PRACTICAL ENGINEER

Trade-mark reg. U. S. Pat. Office

SEMI-MONTHLY

VOL. XIX. CHICAGO, JANUARY 1, 1915 No. 1

Scientific Management in Power Plants

A PRACTICAL APPLICATION IN THE WARRIOR RIDGE PLANT OF THE PENN. CENTRAL LIGHT & POWER CO. THE SYSTEM IS OUTLINED, PRELIMINARY INVESTIGATIONS DESCRIBED, WORK ASSIGNED AND RESULTS NOTED. BY WALTER N. POLAKOV

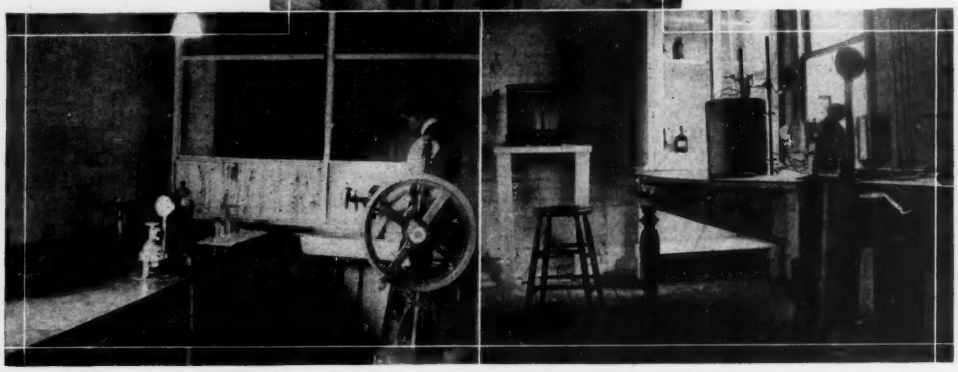
APPLICATION OF PRINCIPLES of scientific management to the manufacture of power was begun by the writer at the plants of the Penn. Central Light & Power Co., in 1912. Part of this work was described in a paper presented at the 1913 Annual Meeting of the A. S. M. E.

The art of management has been defined by Dr. F. W. Taylor "as knowing exactly what you want men to do and then seeing that they do it in the best and cheapest way."

Management cannot be termed "scientific," however, before the knowledge "what you want" and "how to do it" is based on scientific certainty, not on habit, tradition, hearsay, or superficial near knowledge.

Thorough, minute and unbiased research work must necessarily precede the introduction of new methods. No plants are alike in their design, location, supplies, attendance and service. It would be absurd, therefore, to attempt to transplant the practice successful in one plant to another. Each case must be studied individually and while the practice is modified to suit the conditions, the principle remains the same: "Apply scientific analysis and then synthetically devise: 1st aim, and 2nd means."

Upon analyzing any practical problem a man with mathematical turn of mind will find no difficulty to express its condition in some form of an equation. Yet we know that many equations have several possible solutions; some equations with several unknown quantities have an unlimited



FIGS. 1, 4 AND 5. POWER PLANT EQUIPMENT ESSENTIAL FOR EFFICIENT OPERATION. FIG. 1 SHOWS STEAM FLOW METER WITH DRAFT AND FIRING INSTRUCTION SCALE, RECORDING DRAFT GAGE, DAMPER CONTROL AND SPECIAL LAMP. FIGS. 4 AND 5 SHOW VIEWS IN THE LABORATORY CONTAINING EQUIPMENT FOR THE PROXIMATE ANALYSIS OF COAL AND FLUE GAS

or very great number of possible solutions, each satisfying the equation. This is the reason why it is an absurdity to claim that one result will be necessarily obtained from given causes; it is true, however, that the number of possible solutions is reduced by the improbability of some of them. This selection of, first, rational result from the interplay of causes, and second, arrangement of causes to obtain the desired result, constitutes the art of introduction of scientific management. Lack of clear understanding of this fact often creates confusion of methods with principles and forms, and implements with the method.

Outline of the System

The system of management, as installed in 1912 at Warrior Ridge Power Plant, may be briefly described as follows:

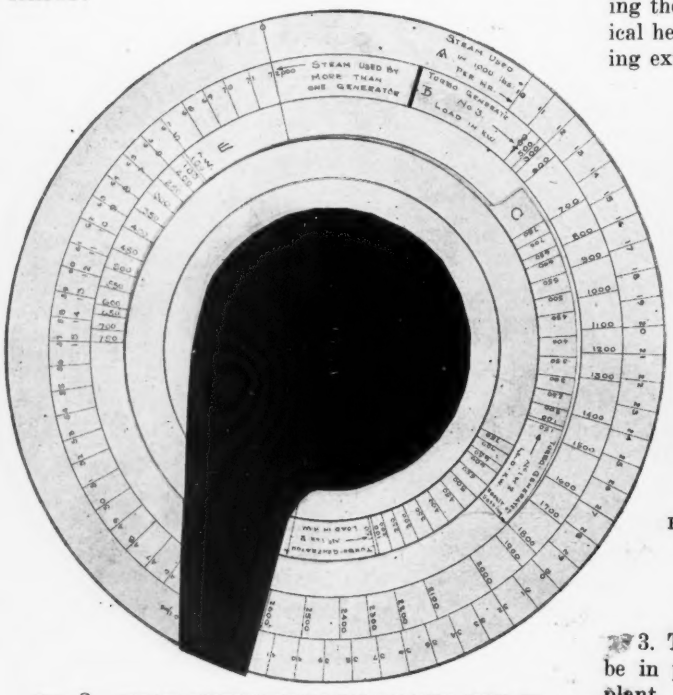


FIG. 2. STEAM CONSUMPTION CALCULATOR USED IN WARRIOR RIDGE PLANT

To find the steam consumption per hour:

1. If No. 1 is running alone, read the inner figures on scale B opposite the given load in kw. on scale E.
2. If Nos. 1 and 2 are running, take the load on one turbine on scale D and set under O line; take the load on the other turbine on scale C and set opposite the arrow on scale D. Read the result on scale A opposite the arrow on scale C.
3. If No. 3 is running alone, read the figures on scale A opposite the given load on scale B.
4. If Nos. 1 and 3 are running, set the load on No. 1 on scale C opposite the load on No. 3 on scale B. Read figures on scale A opposite arrow on scale C.
5. If Nos. 1, 2 and 3 are running set the load on No. 2 on scale C opposite the load on No. 3 on scale B; set the load on No. 1 on scale D opposite the arrow on scale C. Read the figures opposite arrow on scale D.

As a result of thorough tests of all units of equipment, instruction cards were prepared describing in detail the best method of operating each unit, handling each process and performing each detail of work.

Necessary methods were devised and precautions taken to provide all men always with the supplies and tools best suited to the work. Plans were worked out to maintain all equipment in best operating condition and a complete system of records was installed, showing at any time not only results accomplished but also the conditions under which each man worked. Bonus was paid for accomplishment of the task assigned to men, bonus ranging, according to the difficulty of the job, between 10 and 25 per cent. This bonus is paid if the instruction is lived up to, in addition to the daily wage which the man always gets. Bonus is not made larger if results are "better" than required in task, the reasons for this being:

1. For operating thermal processes, a task set with scientific certainty means maintenance of prescribed conditions; results being merely a necessary consequence, can not vary much and do not require additional compensation.

2. For manual labor the task is set within the safe limit of the individual selected for the work. Exceeding the amount of prescribed work may affect the physical health of the workman, and is discouraged by denying extra bonus.

FIG. 6. WELL LIGHTED MACHINE SHOP PROVIDED WITH MACHINES SUITED FOR REPAIR WORK ON EXISTING EQUIPMENT

3. Task set for one process or job, if correct, must be in perfect balance with all other processes in the plant. Exceeding the predetermined economic result in some one partial process may mean changing the standardized condition affecting some other process and cause the final result to be unduly expensive.

Initial Investigation

To find the best result that can be expected from every boiler, turbine, pump, condenser, etc., tests were run and conditions governing the desired result recorded in great detail. Then performance of boilers, for instance, was studied and checked scientifically to see whether the best test was really the best possible, and if not, what could be improved. Thus we found that it is cheaper to run boilers with 73 per cent efficiency, using certain coal, than to obtain 77 per cent with another coal.

Further, by studying the temperature of escaping gases and its effect on the heat balance, we decided that it would be detrimental to the men and to the company to allow the efficiency to drop as soot accumulated on boiler tubes. Therefore, satisfactory automatic soot

blowers were put in to secure uniformity of conditions day by day. We provided firemen with draft gage, steam flow meter and flue gas pyrometer for each boiler, and worked out on the flow meter 2 additional dials, indicating for each rate of driving the corresponding best draft and required thickness of fuel bed.

Firing was regulated first, by bell signal ringing every time 1 ton of water was fed into the boiler, thus calling for 10 shovelfuls of coal, 5 in each furnace, and secondly by flashing from the switchboard a red or green light, indicating whether station load was going up or down.

PENN CENTRAL LIGHT AND POWER CO.

1 SHEETS **GENERAL INSTRUCTION CARD**

ORDER NO.

SHEET NO. 1 Warrior Ridge DISTRICT Electric DEPARTMENT

OPERATION SYMBOL

DESCRIPTION OF OPERATION Passing coal from coal bin to front of boilers in 400 lb. wheel-barrow on concrete floor.

TO BE STARTED 6.42 A.M. 2.42 P.M. 10.42 P.M. TO BE COMPLETED 3.00 P.M. 11.00 P.M. 7.00 A.M.

YEAR	MONTH	DAY	SIGNED
13	10	13	W.N.P.

CHECKED

ITEM	DETAILED INSTRUCTIONS	Unit Time	Time Allowed
1	Get shovel, long handle, 21.5 lbs. capacity		
2	Get wheel-barrow, 400 lb. capacity		
3	Check the scales, get the report sheet and pencil	4 Min.	
4	Open the door of your coal bin	2 min.	
5	Place board to stock coal for next fireman	.18 min.	
6	Shovel coal in wheel-barrow	1.25 min.	
7	Lift wheel-barrow on scale	.12 min.	
8	Weigh by dropping or adding coal	.33 min.	
9	Wheel to front of boiler	.16 min.	
10	Dump and lift barrow	.10 min.	
11	Wheel back to bin	.18 min.	
12	Total time per wheel-barrow, with 20% for incidents	2.55 min.	45. min.
13	After 15 barrows delivered, rest sitting	10.0 min.	55 min.
14	Pass 10 wheel-barrows per above detail instruction	25.5 min.	1 Hr. 20 min.
15	Rest Sitting	10.0 min.	1 Hr. 30 min.
16	Pass 8 wheel-barrows as per above instruction	20.0 min.	1 Hr. 40 min.
18	Rest Sitting	10.0 min.	1 Hr. 50 min.
19	Pass 8 wheel-barrows as per above instruction	20.0 min.	2 Hr. 10 min.
20	Continue above operations until enough coal		
21	is passed		etc.
22	Sweep floor, get tools in shape, lock bin door,		
23	Return the key of the bin and report to the office	10.0 min.	
24			
25	Task is accomplished when within 8.3 hrs. all coal		
26	needed is passed without delays for firemen's work		
27	and instruction observed		
28	Bonus is paid over and above day rate 1¢ per 1000 lbs.		
29	of coal passed during the shift if accuracy of reports		
30	is within 2% of railroad weight.		

THE ABOVE WORK COMPLETED AS DESCRIBED ABOVE SIGNED Walter N. Polakov

FIG. 3. INSTRUCTION CARD FOR COAL PASSER

FIG. 7. TICKLER CABINET

FIG. 8. PLANNING BOARD

Feed water was similarly regulated, the water level being higher when load was light and lowered during peaks, to take advantage of heat stored in boiler water.

Other operations such as cleaning fires are made after a certain number of tons of coal are burned; blowing off soot and blowing down boilers were also covered by special instruction cards.

In a similar manner, the performance of steam and water turbines was tested and studied and instructions prepared for regulation of the amount of circulating water in condensers, temperature of hot well, etc., for most advantageous vacuum.

On the switchboard and in high tension room in the same manner principles of safe and economical operation were investigated and instruction cards prepared.

Loading up turbines in various combinations for various loads was regulated by a special instrument, Fig. 2, showing the best combination of turbines for minimum steam consumption for each load.

Voltage regulation, which is manual, being of great importance for consumers spread in 4 counties and using power for such different purposes as coal mines, residences, municipalities, mills, quarries and railways, was taken care of by an instruction line drawn on an ordinary volt meter chart and revised every time the demand was changed by method of a vector diagram.

Practical Operation

Each of these detail studies and the resulting instruction card is subject for a book, but we cannot afford the space to go into detail here. Suffice it to say that neglect of any of the requirements of an instruction

card makes it impossible to accomplish the task. Figure 3 reproduces the instruction card for passing coal to the boiler room from an adjacent bin. It might be interesting to quote from a report made on the subject:

"* * * 180,000 lb. of coal were handled by 4 men in 24 hr. Two men working together for 12 hr. each day and passing 45,000 lb. each, could not stand the work. It was too hard. This was because the shovel had a short handle and they had to bend too low; because the shovel held only 16 lb. of coal instead of 21½ lb., causing too many bendings per ton; because the wheelbarrow held only 250 lb., causing too many trips. When a man was given the right kind of shovel and a wheelbarrow holding 400 lb., yet throwing less weight on the arms when lifted loaded, he handled 65,000 lb. in 8 hr. (instead of 45,000 in 12 hr.) and thought the job much easier than before. This man, however, was left to himself before the new way of doing the work formed a habit with him. In a short time he came to us complaining of fatigue and refusing to continue the work. We started to watch him again, and the trouble was clear.

"He did not observe the instruction card. This card ordered rest every so often, for so many minutes, sitting. Instead, the man worked much longer at the stretch, thinking that longer rest afterwards would refresh him better, and, when he took his rest, he spent the time standing and chatting to a fellow, not sitting, as prescribed. That was enough to cause fatigue. The rest of the gang of coal passers at Warrior Ridge was finally put on the task in the proper manner, but no complaint has since been heard, and their health and spirits markedly improved."

No task can be accomplished regularly unless supplies, implements and conditions are best suitable for it. The management assumes the responsibility of providing men not only with proper instructions and necessary training, but with required conditions to work under. Every car of coal received is tested in the company's own laboratory and reports reach the plant before the use of the shipment is started.

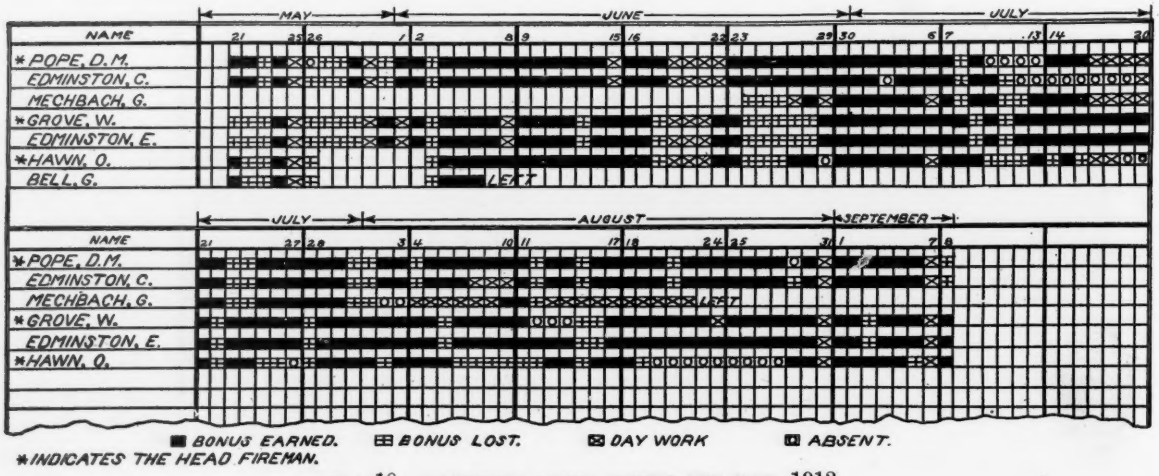


FIG. 10. GRAPHICAL BONUS RECORD FOR MAY, 1913

In this way, not only compliance with specifications is known, but, what is more important, firemen are provided with an instruction card prepared especially for the grade of coal they have to fire. Guesswork and mistakes are thus eliminated, exact knowledge from previous experiments being substituted. A simple coal testing laboratory like this, equipped at a cost of a few hundred dollars, to make proximate analysis, saves thousands of dollars.

Special men, not of the operating crew, are engaged to do the maintenance work and inspection of all plant equipment and machinery. The maintenance man is on bonus, which he loses if, due to his neglect, the scheduled unit cannot be operated efficiently, breakdown occurs or the operating man loses his bonus due to imperfect condition of the units he operates.

In order to see: 1. Whether supplies and equipment are taken care of properly and are available at the right time: 2. Whether men are getting necessary instructions and training: 3. Whether they perform their tasks in the prescribed manner, and what are the results;

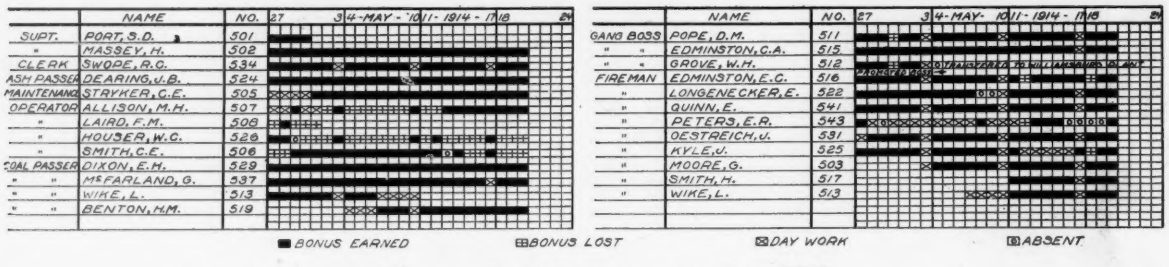


FIG. 11. BONUS RECORD FOR MAY AND JUNE, 1914

the plant office was organized along the following lines. Storerooms in the power plants are branches of the general store of the company. They carry in stock standardized material, each article having designated "amount to order" each time and "order point," at which stock should be replenished. A symbol is shown on each tag attached to each bin and each store issue is marked on the tag, so that the balance on hand is always known at a glance, also from the "balance of stores card" kept in the general office, one card for each article. As soon as the balance reaches "order point," a new lot is ordered. Such a system furnishes us with a permanent inventory and insures against the shortage of any article in store.

Schedules for inspection, repair, and regular overhauling of equipment, as well as all other matters which are to be brought up at a certain time to somebody's attention, are handled through the "Tickler System." The tickler cabinet, as shown in Fig. 7, has 14 drawers, one for each month of the year with folders for each day; the right drawer serves to receive all notes accumulated during the day; the left top drawer has 24 hourly folders for matters to come out at a definite hour of the day.

In the tickler system, all notes, orders, unanswered letters, etc., are kept in folders for the day when they shall come out—then the clerk distributes them to proper parties, either early in the morning, or distributes them first in hourly folders for the day if certain things must be called to the attention of some one at a definite time. In this manner, not only the chance to forget something is eliminated; but repairs, inspections, etc., are done at regular intervals, which proves to be the safest way of avoiding "emergency" repairs and reduces maintenance cost.

Planning the Work

Thus far planning has affected material and schedule; in addition to this, men are assigned to do certain work in accordance with: 1. Their skill for particular work; 2. Time machines are available; 3. Time men are available; 4. Time supplies and implements are ready. To take care of this, the planning clerk is provided with a "Planning Board."

On this planning board for each employe there are 3 hooks; on the lower, ticket is placed for a job "in mind" for a man; on the middle is placed ticket for job for which tools, material and machine are "ready," and on the upper, ticket showing the job "now" being done by the man. At the time the protograph was taken the board showed that out of 32 employes 3 were absent, one position was vacant, all have work assigned to them, 2 absent men have jobs waiting for them, 2 men have jobs assigned to them but not ready, 8 men have work provided for them and ready for start.

One of the most important functions of the planning office is record keeping. All logs, records, curve drawing instrument charts, etc., are turned over to this office daily and worked out in detail to determine: 1. Thermal efficiency of each process; 2. Condition under which job was done; 3. Cost of each stage of operation; 4. Bonus of each man, if earned, or reason why it was lost.

Data of the first 3 groups are briefly reported on form Fig. 9, whereas for bonus record a graphical method was adopted, as shown in Figs. 10 and 11. Incidentally, comparison of bonus records one year after task with bonus plan was started with first few months after it was started, shows quite marked progress. To give an illustration of what has been accomplished by this method, we may quote average boiler efficiency for January, 1913, before the new method of management was inaugurated; for May, 1913, first month under new method, and May, 1914:

January, 1913...56.2 per cent Boiler and grate efficiency
May-June, 1913..70.8 per cent Boiler and grate efficiency
May-June, 1914..73.4 per cent Boiler and grate efficiency

Time and cost keeping are also functions of the planning office. In this connection, it is interesting to note that all time cards, store issues, etc., are of the form convenient for use on the U. S. Census Machine. To facilitate the tabulation and charging to proper account, H. W. Reed of Day & Zimmerman, worked out the methods of symbolizing all items so that classification in any desired grouping is feasible with remarkable ease and speed, and at materially lower cost than by wearisome common methods of bookkeeping.

Photos 13, 14, and 15, show the 3 stages of working out these returns—punching cards in accordance with charge symbol, and data conveyed; automatically sorting cards in any desired group of charge; and automatically totalizing and tabulating.

We can not put too much emphasis on the importance of a well organized planning office for economical opera-

DAILY POWER PLANT REPORT

PENN CENTRAL LIGHT AND POWER CO.
STATION Warrior Ridge — FOR 24 HOURS ENDING 9 6 13 7

BOILER ROOM	WATCH 1	WATCH 2	WATCH 3	ENGINE ROOM	WATCH A	WATCH B	WATCH C
COAL USED	52000	50000	31800	HYDRO ELECTRIC OUTPUT	1300	2240	60
WATER EVAPORATED	449000	430000	265500	STEAM GENERATED OUTPUT	22700	22560	14840
ACTUAL EVAPORATION	8.66	8.62	8.35	LOAD FACTOR	68.5	68.3	62.1
FACTOR OF EVAPORATION	1.2125	1.2159	1.2051	STEAM PER KWH	19.78	19.07	18.00
EQUIVALENT EVAPORATION	10.49	10.48	10.05	COAL PER KWH	2.29	2.21	2.15
EFFICIENCY OF GENERATION	73.9	73.8	70.8	THERMAL EFF-CY. OF PLANT	10.85	11.22	11.54
COST OF FUEL PER 1000 LBS. OF STEAM	0.0823	0.0814	0.0848	COST OF FUEL PER KWH	0.00198	0.00189	0.00206

REMARKS:

COAL USED FOR BANKING 1 " BOILERS DURING 6 8 HRS. 55 40 MIN. 5000 LBS. COAL ANALYSIS BTU AVE. B.T.U. 13800

TOTAL OUTPUT 63700 KW HRS. SIGNED S. D. Port

FIG. 9. DAILY REPORT

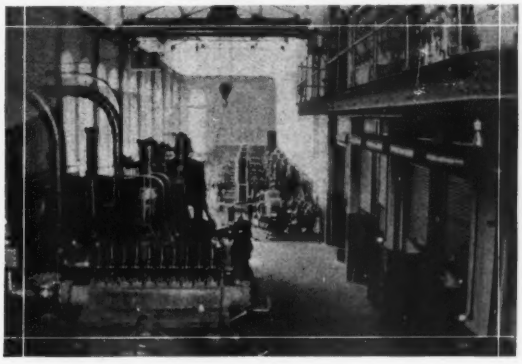


FIG. 12. INTERIOR VIEW OF WARRIOR RIDGE PLANT

tion of a power plant. If in manufacturing establishments it proves to be of great value to substitute careful planning of work for hazardous progress of an order through the shops, in a power plant its parallel duty is to plan the load for units and scheduling repairs, thus materially improving load factor and reliability of service.

Whereas, in a factory, instruction cards eliminate the guess of workmen as to sequence and speed of operations, in a power plant, instruction cards convey to men exact knowledge of best conditions, proper determination of which requires a thorough familiarity with thermodynamics, mechanics, chemistry and theory of electricity —a volume of knowledge that can not be expected from all power plant employes. A planning office in a power plant, concentrating all available knowledge on the subject and directing its proper use, is incidentally ready to perform a new function, heretofore done by accountants and financiers. The planning office knowing what will be done and how, knows how much it will cost, so that it is possible to predetermine the cost of maintenance and operation. It is now simple to establish standard cost or how much a kilowatt-hour shall cost at a given output. It is important to know how much the current costs, that is, to account for expenses incurred, but it is more profitable to know whether that cost was reasonable and still more important to tell how it could be reduced. And this is done by application of scientific management to power plants and through the planning office.

During the first year this system was in full operation, the Warrior Ridge plant saved 13.2 per cent in all expenses chargeable against it over the total expenses for the 2 previous years. This total reduction of all expenses, not unit cost, coincided with increased output, hence it appears that at about 7/8 of the expense, the company generated 1⅔ times the amount of current.

More economical operation of plants in no instance means harder work for employes. In fact, the reverse is true, as there is less coal to shovel, less emergency repair work done, less exciting, nerve-racking responsibility on the part of the employe. It means to the company greater profit; and the men, realizing that under the new regime their services become more valuable, rightly expect extra compensation in the form of a bonus for the accomplished task. If you say to the employe: "We want a certain result and will pay you more the nearer you are to the goal"—you offer a premium, not a bonus. If you say to them: "We will teach you how to do things and if you learn to do them correctly, we will give you extra compensation," you offer a bonus.

This distinction is not merely of words, it is radical. In the first case you confess that you do not know how to run the plant, and want your employe to manage the plant for you, in the second case you lead and help the men, you manage your plant, because you know how.

FIG. 13. PUNCHING CARDS

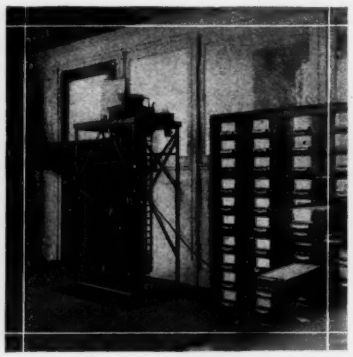


FIG. 14. SORTING MACHINE AND CARD FILE

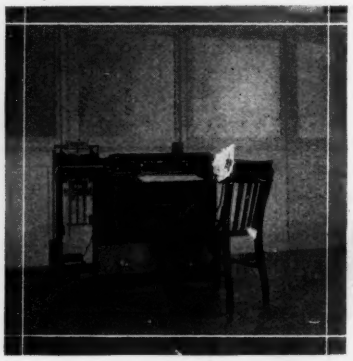


FIG. 15. TABULATING MACHINE

The Boiler Plant

By R. T. Strohm

HERE is a huddle of bulky machinery
Banded with iron and buttressed with brick;
Piping, like serpents in Stygian scenery,
Crawling in corners where shadows are thick;
Eyes gleaming redly and maws gaping luridly,
Hissing and roaring and rumble and din—
Not an alluring abode, yet assuredly
Here's where economy ought to begin.

Stokers who tend to their furnaces heedlessly,
Deaf to advice and too stubborn to learn,
Add to the weight of their burdens, and needlessly
Waste a great part of the fuel they burn.
Firing, to them, is a species of slavery,
Coal is the black, smutty stuff in the bin;
So, to discourage such blundering knavery,
Here is where efforts to save should begin.

Here is no welcome for those who are finical,
Trained to abhor the suspicion of dirt,
Taught to regard, with an eye coldly cynical,
Anyone wearing a hickory shirt;
But, if some fellow in every community,
Careless of smudges of soot on his skin,
Hankers to tackle a big opportunity,
Here he will find a good chance to begin.

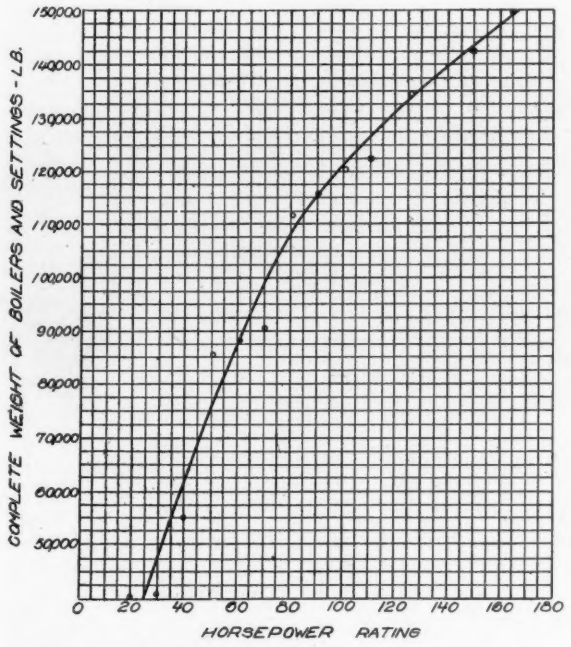
Now, with the New Year, when each one ambitiously
Makes his resolves for the annual round,
You who are stokers, begin it auspiciously,
Vow that the habits of waste shall be downed.
Don't spend the minutes in dubious pondering
Over the methods of working to win;
Any old place where there's wasting and squandering
Gives you the challenge and bids you begin.

Boiler Foundations

PREPARATION OF SOIL; CONCRETE; BEARING POWER OF SOILS; CALCULATIONS

IN SELECTING THE LOCATION of boilers, attention should be given to the nature of the soil upon which they are to rest. It is always better to construct a foundation for the walls to rest upon, sufficient to insure permanent alinement. For a firm soil, the foundation may be light, but if the soil is sandy or moist, the foundation should be heavy and broad.

Having determined the approximate floor space to be occupied by the boiler, the soil should be removed to the proper depth and for a distance of about 2 to 3 ft. from the outer wall line. After having leveled off that part of the ground upon which the foundation is to rest, the forms for the concrete may be built up in place. In doing this, it is necessary to have the interior



RELATION BETWEEN HORSEPOWER AND WEIGHTS OF HORIZONTAL RETURN TUBULAR BOILERS

walls of the forms as plane and smooth as possible and it is advisable either to cover these with paper or wash them with a solution of soft soap, so as to facilitate removal of the boards after the concrete has hardened. It is desirable to spread a well tamped layer of ashes or gravel on the ground before pouring the concrete. If it is at all possible, the entire foundation and ashpit should be laid at one time, tamping the concrete well into place, as by allowing one section to harden before the entire mass is formed, the foundation has a tendency to be weak.

It is best to have the ashpit below the level of the floor, for the reason that it is the practice among firemen to wet the ashes before drawing them out, and if the pit is not so placed, the water will flow out onto the floor. Also, ashes filling the pit, tend to cut down the effective cross-sectional area required for the proper amount of air.

TABLE I. MATERIALS FOR CONCRETE

Proportions of Mixture			Material for One Cubic Yard Concrete								
			Gravel ¼ in. and under			Stone 1 in. and under, dust screened out.			Stone 2½ in. and under dust screened out.		
Cem't	Sand	Stone	Cement Bbls.	Sand Yds.	Stone Yds.	Cem't Bbls.	Sand Yds.	Stone Yds.	Cem't Bbls.	Sand Yds.	Stone Yds.
1	2	3	1.54	0.47	0.73	1.70	0.52	0.77	1.73	0.53	0.79
1	2	4	1.54	0.41	0.81	1.48	0.44	0.89	1.48	0.45	0.90
1	2	5	1.17	0.36	0.89	1.27	0.39	0.97	1.29	0.39	0.98
1	2½	4	1.34	0.47	0.73	1.35	0.52	0.82	1.36	0.53	0.84
1	2½	5	1.10	0.42	0.85	1.19	0.46	0.91	1.21	0.46	0.92
1	2½	6	0.98	0.37	0.89	1.07	0.41	0.97	1.07	0.41	0.98
1	3	5	1.03	0.47	0.78	1.11	0.51	0.85	1.14	0.52	0.87
1	3	6	0.92	0.42	0.84	1.01	0.46	0.92	1.02	0.47	0.93
1	3	7	0.84	0.38	0.89	0.91	0.42	0.97	0.92	0.42	0.98
1	4	6	0.83	0.51	0.77	0.90	0.55	0.82	0.92	0.56	0.84
1	4	7	0.77	0.47	0.81	0.83	0.51	0.89	0.84	0.51	0.90
1	4	8	0.71	0.45	0.86	0.77	0.47	0.93	0.78	0.48	0.95
1	4	9	0.65	0.40	0.89	0.71	0.45	0.97	0.73	0.46	1.01

Ashpits are one of 2 types, those on a level, or nearly so, with the boiler room floor and those in which the ashes drop into a pit or pocket below. In the former, the general tendency is to have the floor of the pit slope toward the bridge wall as shown. By studying the illustration, however, it can be seen that a funnel effect should be obtained by allowing a short drop at the ash-

TABLE II. BEARING POWER OF SOILS*

Kind of Material	Bearing Power in Tons per Square Foot	
	Minimum	Maximum
Rock - the hardest - in thick layers, in native bed	200	
Rock equal to best ashlar masonry	25	30
Rock equal to best brick masonry	15	20
Rock equal to poor brick masonry	5	10
Clay on thick beds, always dry	4	6
Clay on thick beds, moderately dry	2	4
Clay, soft	1	2
Gravel and coarse sand, well cemented	5	10
Sand, compact and well cemented	4	6
Sand, clean, dry	2	4
Quicksand, alluvial soils, etc	0.5	1

*Ira O. Baker, "Treatise on Masonry Construction."

pit door with a gradual rise toward the bridge wall, giving the air admitted below the grates a better and more correct path of travel, and making it easier to clean the ashpit.

For a ground level pit, fill in below the ashpit space with well-tamped ashes or gravel, topped by 4 in. of

TABLE III. WEIGHTS OF HORIZONTAL RETURN TUBULAR BOILERS

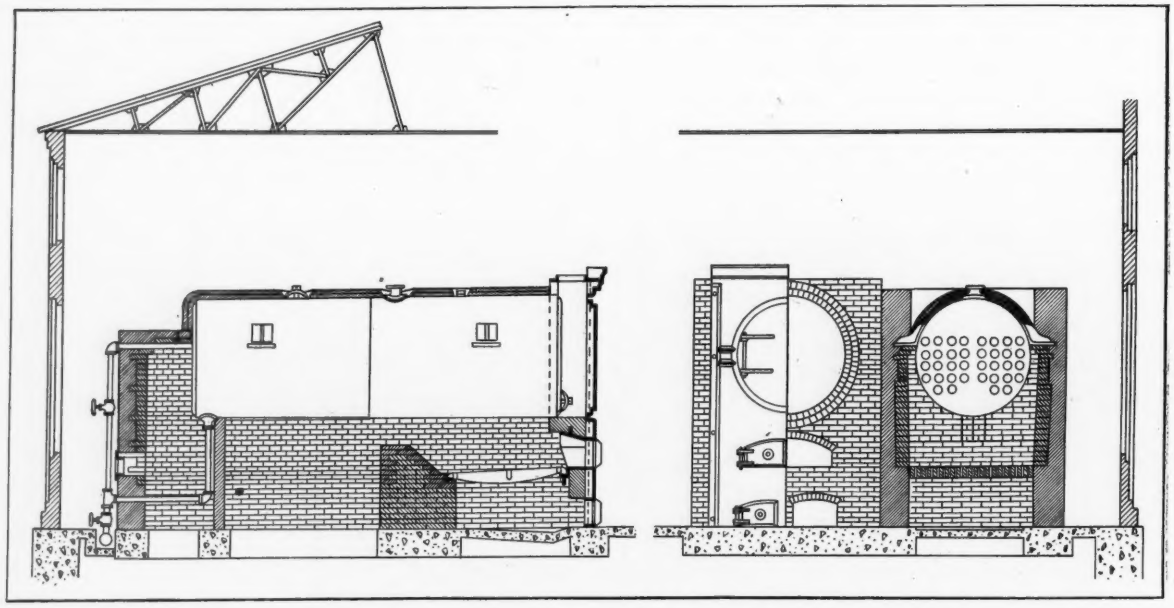
Horsepower	Dia. of Shell, In.	Len. of Shell, Ft.	No. of Tubes	Dia. of Tubes	Weight of Boiler	Wt. of Boiler and Settings
20	36	10	28	3	4700	40300
30	44	10	36	3	6800	41350
40	44	14	36	3	8400	56100
50	48	16	28	4	10500	86750
60	54	14	36	4	11800	88150
70	54	16	36	4	12700	90450
80	60	16	44	4	14900	111900
90	60	18	44	4	16300	113500
100	66	16	54	4	17500	122250
110	66	18	54	4	19000	122750
125	72	16	70	4	21000	134500
150	72	18	70	4	23000	142000
165	72	20	70	4	25000	149250

cinders to within 3 or 4 in. of the desired level and slope of the ashpit floor. Then build up and place the forms of the pit (together with the foundation forms) so that when the concrete is poured and surfaced, its upper surface is at the desired level.

Having removed all forms from around the foundation and the ashpit, preparations may be made for the

setting proper. If the upper surfaces of the concrete foundations have been left rough, in order to secure a good bearing surface for the bricks, it is well to slush the top with cement of a mixture such as generally used for sidewalks, thus giving a smooth and even surface upon which to build.

For boiler foundations, a 1-3-5 concrete, composed of 1 part cement, 3 parts sand and 5 parts crushed stone, is good. Using stone 1 in. and under, with the dust screened out, 1.11 bbl. of cement, 0.51 cu. yd. of sand and 0.83 cu. yd. of crushed stone would be required for each cubic yard of concrete.



GENERAL VIEW OF TUBULAR BOILER, SHOWING SETTING AND PROPER LOCATION IN BOILER ROOM

The accompanying table contains the proportions of the mixtures and the amounts of the various constituents required for 1 cu. yd. of concrete.

The foundation of a 150-hp. horizontal return tubular boiler, 18 ft. by 72 in. and having 76 4-in. tubes, occupies a floor space of about 10 by 24 ft. or 240 sq. ft. and as with fittings and setting it weighs 142,000 lb., the unit weight on the foundation will be 591 lb. per sq. ft. This is the value of the unit weight when the foundation consists of a slab of concrete under the entire boiler, a form necessary only on soils of unusually low bearing power. Assuming the foundation is to set on a soft clay, the bearing power of which we find from the table of Bearing Power of Soils to be a minimum of 2000 lb. per sq. ft., we find that but 71 sq. ft. of bearing surface are necessary, which may be placed so that it is well under the rear and side walls, bridge wall and front. Allowing 24 in. for each side, rear and front walls, and 48 in. for the bridge wall, we have a total bearing surface of approximately 144 sq. ft., or 73 sq. ft. in excess of the amount required, giving a factor of safety of over 2.

Placing this to a depth of 2 ft., the total amount of material required will be 2×144, or 288 cu. ft., or $10\frac{1}{2}$ cu. yd., calling for nearly $11\frac{3}{4}$ bbl. of concrete, $5\frac{1}{2}$ cu. yd. of sand and 9 cu. yd. of crushed stone.

Suspension

TUBULAR boilers are supported by means of brackets riveted to the shell and resting on the setting, by some form of overhead suspension through the medium of hook brackets and slings swung from a framework of structural steel or by front brackets and roller at the rear end.

In the bracket type of support, the front brackets as a rule rest on the setting, while those at the rear of the shell bear upon small rollers and bed plates so as to compensate for all longitudinal movement due to expansion and contraction. Cast or pressed steel brackets of channel or I section are generally used. In the majority of cases, it is found that these brackets are riveted only above their bearing surface, a form of construction not to be highly recommended. For the proper degree of security, it is well to have an additional row of rivets below the bearing surface.

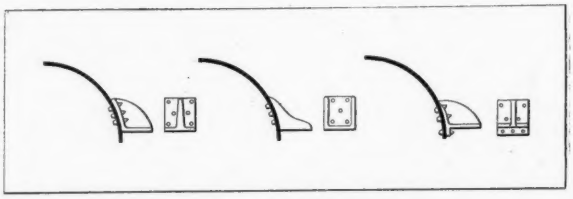


FIG. 1. BOILER BRACKETS

On boilers 15 ft. or less in length, but 2 brackets on each side are necessary, while boilers over 15 ft. long are usually provided with 3 on each side, this construction requiring particular care to secure the proper distribution of load on each bracket.

In the case of the water-tube boiler, an additional type of support is employed, a cast or built-up saddle to carry the drums. Water-tube boilers may be suspended

by any one or a combination of the above 3 means. Due to the drums of these boilers being comparatively smaller than that of a tubular boiler, the supporting link is passed under the shell instead of being connected to a hook bracket, as this is not only a cheaper construction but also safer, requiring no punching or riveting of the sheet, as when some form of bracket is used. Some manufacturers whose boilers have a lower drum connected by tubes to one or more upper drums depend upon these connecting tubes as sufficient suspension for the lower drum. Due to the strains placed upon these tubes tending to cause leaks, it is preferable to place saddles below this drum.

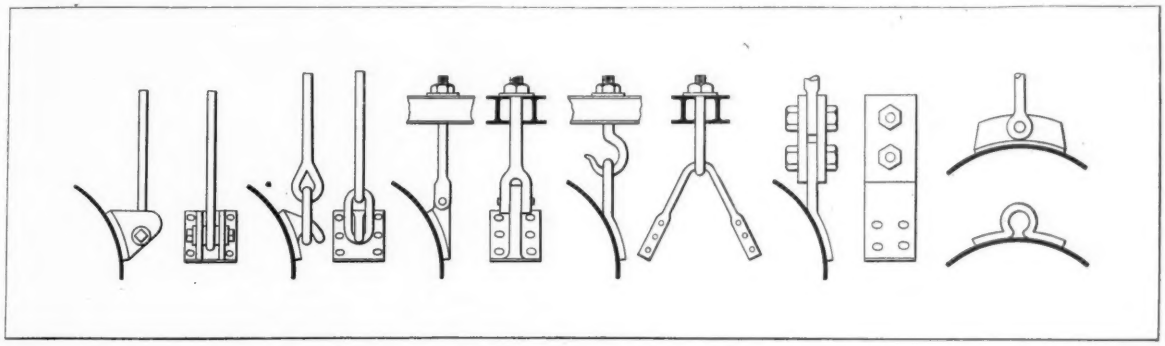


FIG. 2. HOOK BRACKETS AND SLINGS

Walls

HAVING moved the boiler to the point where it is to be erected, it is raised by jackscrews or levers to the height at which it is to set, and then blocked by cribbing made of short pieces of timber, as shown in the illustration. With the boiler in place, the back end being 1 in. lower than the front end, in order to drain properly to the blowoff, the front is put in position and propped up until the walls have been carried up far enough to allow of through bolts or anchor rods being inserted to hold it in place. The walls are carried up to the full height on the sides, pockets being left for the brackets when such are used; buck staves are put in place and the rods drawn up snug. Before removing the cribbing so that the weight of the boiler rests on the walls, the brickwork should be allowed to dry out and care should be taken to see that the lugs bear squarely on the sole plates so as not to put a racking strain on the shell or walls. After all is complete, the shell may be closed in.

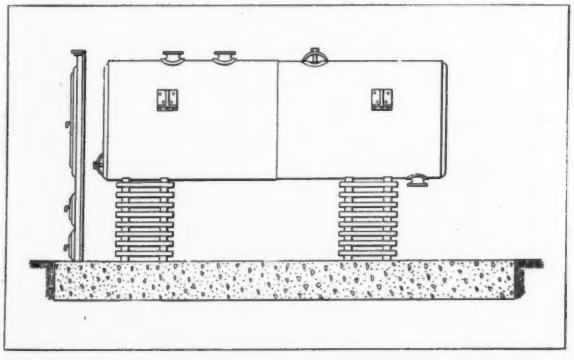


FIG. 1. SHOWING BOILER AND FRONT IN PLACE, READY FOR BRICK WORK

If the top is to be covered with a brick arch, strips of wood are laid lengthwise on the shell and the arch of brick laid on these strips. As soon as the fires reach the wood, it will be burned, and the bricks will settle slightly but not sufficiently to rest against the shell. If a nonconducting covering is used, it should be material which will not absorb and hold moisture, as this will produce corrosion on the top of the shell. If the boiler is to be slung from steel work, this may be erected after the cribbing is in place and the boiler hung directly

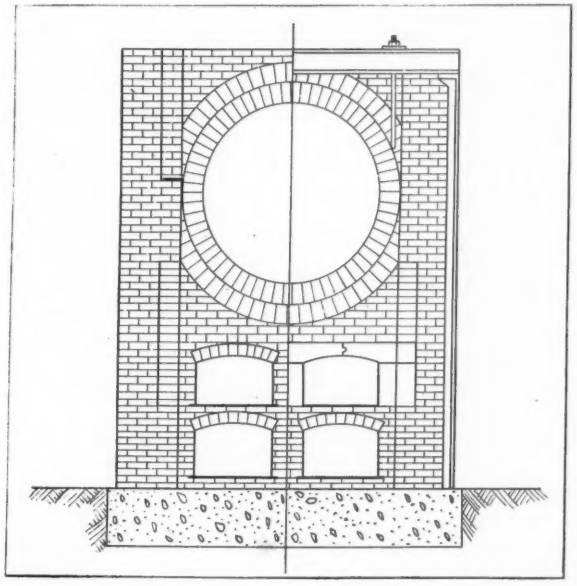


FIG. 2. FRONT END OF SETTING, SHOWING USE OF FIRE BRICK LAID AS HEADERS, AND SPECIAL BLOCKS; LEFT OF ILLUSTRATION SHOWS POCKET IN WALL WITH SOLE PLATE; OPPOSITE SIDE ILLUSTRATES USE OF OVERHEAD SUPPORTS

from the channels. The verticals must be properly stayed, however, while the walls are being built.

The walls are built of common and firebrick, the general practice having been to build them with an air space, as it was believed that since air is a poor conductor of heat these spaces built in the walls of a furnace would prevent or reduce the dissipation of heat through them. There may be a few instances in which such construction of furnace walls reduces the rate of heat loss through them, but in extensive experiments conducted by the United States Geological Survey, it was found that in most cases the effect of air spaces is just the opposite, and appreciable gain resulted by the use of solid furnace walls. If, on account of unequal expansion, it is necessary to build these walls double, the space between should be filled with some solid, nonconducting material.

Grate Support

In the ordinary hand-fired furnace, the grate support is furnished by strips at front and back of the furnace chamber, the front strip supported on the front setting and the rear strip on the bridge wall and at such a height that the grates are inclined about 3 in., as illustrated. The special types of shaking grates on the market today are, as a rule, supported by a cast-iron or steel framework setting on legs so as to do away with settings imbedded in the brickwork. Mechanical stokers also have independent settings.

In deciding on the distance from the grate to the boiler shell, it should be remembered that a bituminous coal requires a greater volume of fire box and a greater height from grate to boiler shell than does anthracite. In laying out a fire box it should also be remembered that grate bars are made in certain lengths, and if the furnace is laid out without regard to the lengths, special bars will have to be ordered, which will cost several times as much as stock patterns.

Closing Cracks

Cracks in the brickwork of a boiler, no matter how minute, are a source of great loss and should be stopped as soon as possible. It is advisable to go over all brickwork every time a boiler is shut down for cleaning, and point up all cracks, filling the larger ones with asbestos. After this is done, all invisible leaks may be stopped by giving the walls a heavy coat of paint so that this may soak in and in that way stop any and all small leaks present.

Metal Covering

As a further aid to prevent the infiltration of air through boiler settings, these have been covered with a sheet metal covering. Due, however, to the great amount of labor rquired to move these when repairs become necssary to the brick work, they have not come into extensive use.

Clean-out Doors

When possible, 2 clean-out doors should be provided for the combustion chamber. When one is used, it should be in the center of the setting, and if 2 are used, one should be placed far enough to one side of the blowoff pipe and protecting pier so that a hoe can readily be worked around it to draw the ashes and soot to the rear end. The other door should be put in the side wall away from the rear door, thus giving access to all parts of the combustion chamber. If a pier is used in supporting the rear end of the boiler, wing walls are usually put in which extend from the pier to the side of the setting so as to give the pier stability. In this case a special clean-out door should be provided in one of the side walls between the bridge wall and the pier wall.

Settings

To facilitate repairs, aid in cleaning and present a pleasing appearance, all boilers have some form of a metal front. This, in the case of the water-tube boiler, extends over the entire front end of the structure, while tubular boilers have what are known as full fronts and half fronts. In the case of the full front the flue connection is placed back of the front, while with a half front it is placed forward so as to project ahead of the rest of the setting.

To estimate the number of brick in a wall, multiply the length of the wall by the width and height, all in inches, and divide by 82 for common brick, or 116 for firebrick. If the lining of the furnace is to be made all headers, multiply the firebrick required by that part of the wall by 2.6, or multiply the area to be laid by 12.

In estimating the material required for a boiler setting, 250 lb. of lump lime and 1 cu. yd. of sand will be needed for each 1000 brick in the walls, and from 800 to 900 lb. of fire clay for each 1000 firebrick in the furnace lining. The necessary amounts of materials required for various sizes of tubular boilers are given in tabular form.

DIMENSIONS OF SETTINGS OF HORIZONTAL RETURN TUBULAR BOILERS

Size		Walls				Spacing, Shell to Side Wall, In.
Diam. In.	Len. Ft.	Solid Bk. and Side In.	½ Arch Front In.	Full Front In.	Bridge Wall In.	
30	8	13	9	12	14	2
32	8	13	9	12	14	2
32	10	13	9	12	14	2
36	8	13	9	12	18	3
36	10	13	9	12	18	3
36	12	13	9	12	18	3
36	14	13	9	12	18	3
36	16	13	9	12	18	3
40	10	13	9	16	18	3
40	12	13	9	16	18	3
40	14	13	9	16	18	3
40	16	13	9	16	18	3
42	12	16	9	16	18	3
42	14	16	9	16	18	3
42	16	16	9	16	18	3
44	12	16	13	16	21	3
44	14	16	13	16	21	3
44	16	16	13	16	21	3
44	18	16	13	16	21	3
48	12	18	18	18	21	3
48	14	18	18	18	21	3
48	16	18	18	18	21	3
48	18	18	18	18	21	3
54	12	18	18	18	24	4
54	14	18	18	18	24	4
54	16	18	18	18	24	4
54	18	18	18	18	24	4
60	12	20	20	20	24	4
60	14	20	20	20	24	4
60	16	20	20	20	24	4
60	18	20	20	20	24	4
60	20	20	20	20	24	4
66	14	20	20	20	26	4
66	16	20	20	20	26	4
66	18	20	20	20	26	4
66	20	20	20	20	26	4
72	14	20	20	20	30	4
72	16	20	20	20	30	4
72	18	20	20	20	30	4
72	20	20	20	20	30	4

Furnace Construction

Interior construction of the boiler furnace is of vital importance, as upon this depends, to a great extent, efficient operation. Various forms of arches, ignition walls, bridge walls and combustion chambers have been tried, some of the most successful types being shown.

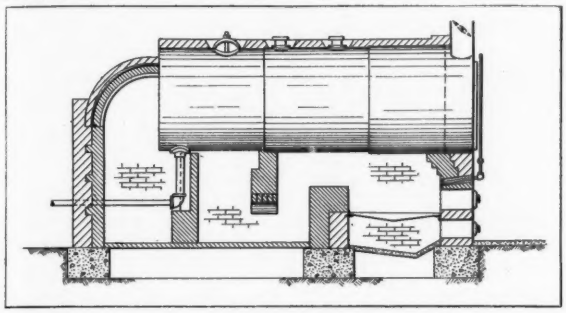


FIG. 1. ARCH USED WITH STEAM JET TO REDUCE SMOKING

The simplest form of arch, shown in Fig. 1, was originally used in connection with steam jets to keep down smoke in the furnace; while it broke up the gases and mixed them to a certain extent, it did not provide

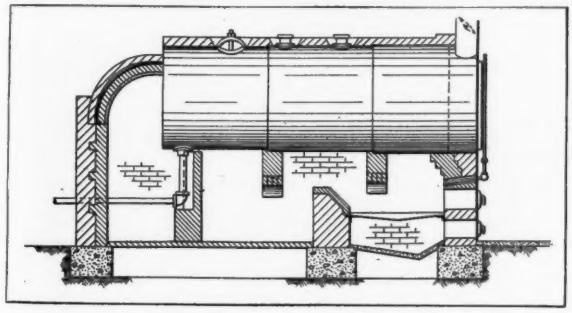


FIG. 2. DOUBLE ARCH SETTING

sufficient temperature at the point of mixture. Two arches were then used, one, as shown in Fig. 2, back of the bridge wall, and the other at about the same height and the same distance in front of the bridge wall, but

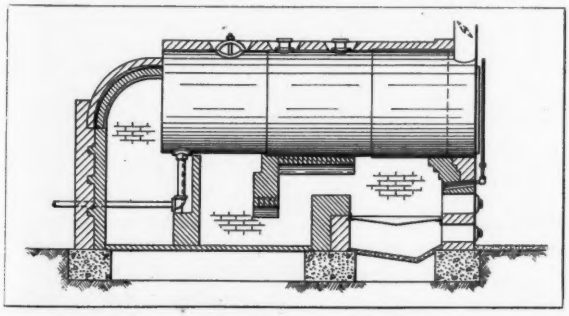


FIG. 3. SINGLE SPAN DEFLECTION ARCH

this construction also had its shortcomings, so the single arch bridge-wall furnace with single-span deflection arch was developed and has been used with success in connection with high volatile coals. From experience, it has become evident that in order to burn high-volatile coals, draft is more essential than high temperatures.

It has also been found that a "cool" furnace, one having direct radiation from the fire to the heating surface, not only increases efficiency and capacity by increasing heat absorption, but reduces the liability to dense smoke because the volume of volatile gases passing off is at no time in excess of the capacity of the furnace to take care of it. As a result, in the furnace shown in Fig. 3, there is provided a zone of high temperature back of the bridge wall and which maintains the gases at or above the igniting temperatures. A deflection arch is provided as shown, against which the high-temperature gases impinge. A sufficient quantity of air is necessary to mix in this high temperature zone with the volatile gases and furnish the necessary oxygen for complete combustion.

Figure 4 shows a double arch furnace with mixing arch for return tubular boiler settings, a form of construction well suited where high volatile coals are burned. The type of furnace such as shown in Fig. 5,

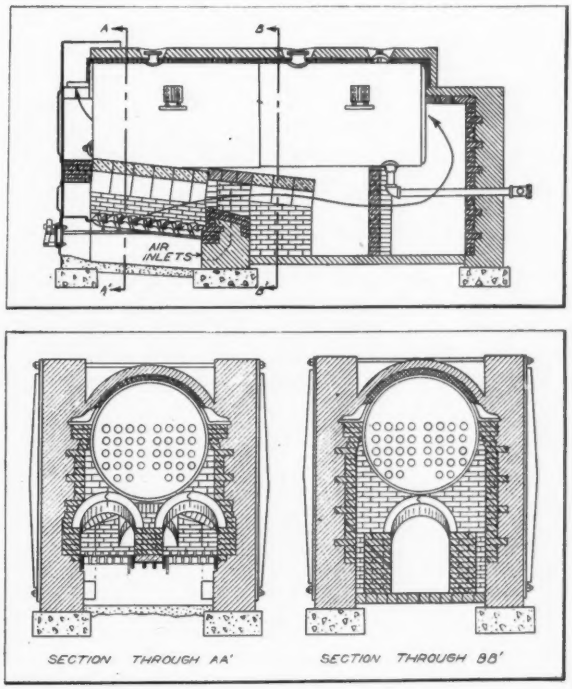


FIG. 4. DOUBLE ARCH FURNACE WITH MIXING ARCH

depending on long flame chambers, is best suited for coals rather low in volatile matter, as they will generally provide sufficient mixing in connection with the length of combustion chamber to prevent the formation of smoke.

Bridge Walls

The simplest form of bridge wall is shown in the cut, page 8. This is often modified by extending it toward the rear with a gradual downward slope. The rear part of this wall may be built in with the wall itself or a filler of earth or ashes may be employed if desired. Considerable difference of opinion exists among engineers and firemen as to the relative advantages of a rear filler or an open space back of the wall,

some contending that an open space acts as a mixing chamber, while others claim that with the filler the gases have a more natural path of travel.

"Wing wall" furnaces for smokeless combustion as designed by Kent, provide for a bridge wall as shown in Fig. 6. In this, C is a fire chamber or oven, built of brick and extending in front of the boiler, where the fuel is burned either on the ordinary grate or by means of a mechanical stoker. D is an ordinary bridge wall. EE^1 are 2 tall vertical walls called wing walls built some distance in the rear of the bridge wall. G is a combustion chamber, HH are several piers of firebrick projecting into the chamber, G, from the rear wall J, K is an ordinary baffle, and M is a tile roof to the chamber, F, to prevent the gases in that chamber from reaching the tubes until after they have passed through the narrow vertical passage between the wing walls, EE^1.

Firebrick Lining

In putting in the firebrick lining, care should be taken to lay it so that it can be replaced without taking down the outer walls of the setting; but at the same time, it must be bonded into the brick work so that it will not peel off. The firebrick is laid up with fire clay mortar, the least possible amount being used in order

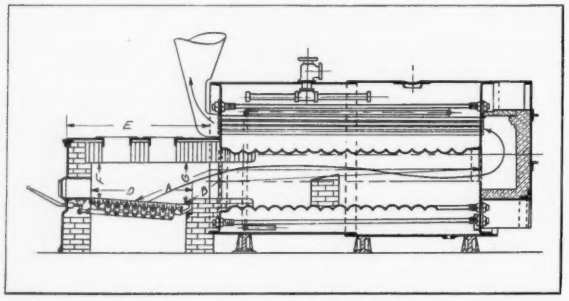


FIG. 5. TYPE OF FURNACE SUITABLE FOR COALS LOW IN VOLATILE MATTER

to give a firm construction. Some engineers line the furnace with brick laid in the same manner as the wall, i.e., with bricks running lengthwise of the setting and every sixth or seventh row laid as headers, bonding back into the main wall. If properly laid, this construction may work well, but the preferable method is to use all brick as headers, i.e., with the ends toward the inside of the wall, for the sides of the furnace above the grate and for the combustion chamber to a point about 2 ft. back of the bridge wall. This avoids the falling out of the stretcher rows of brick and produces a construction in which, if bricks fall out or chip off, they can be turned end for end and still be serviceable for a long time. On the furnace side, the bridge wall is also lined with firebrick laid in fire clay. This subject is taken up in detail under Materials for Settings and Baffles.

Boiler Coverings

To prevent losses due to radiation, the top of the boiler, which extends above the setting, should be covered with some form of insulating material, such as sand, brick, mineral wool or asbestos. If the top of the setting extends to the top of the shell, the space between is filled with sand, mineral wool or asbestos well packed. If the setting walls do not extend to a height greater than the water level in the boiler, the covering can be made up of either 2 or 3 courses of common brick or molded asbestos, or both, placed so as to cover all exposed parts of the shell, as illustrated.

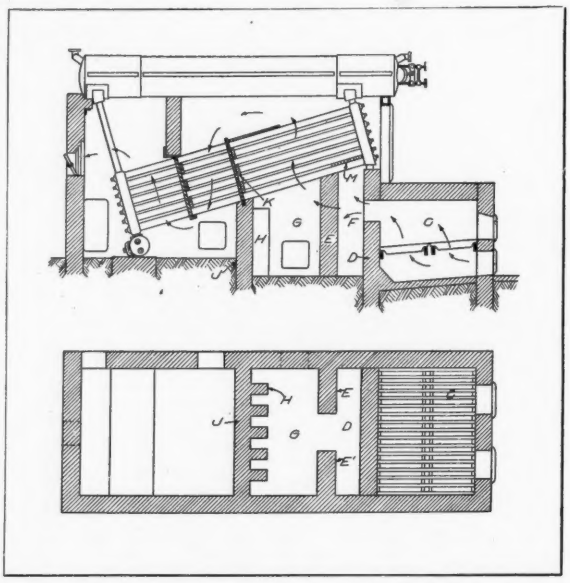


FIG. 6. THE KENT WING WALL FURNACE

Generally, although not always, buckstaves connected by means of through-rods are used to hold the walls in place. Each side wall may have 3 of these while the rear wall will be well supported by 2. The rods holding the rear buckstaves terminate in the metal front which acts as one large buckstave.

Materials for Settings and Baffles

FIREBRICK for furnace linings cannot be judged as to its good or bad qualities without subjecting it to actual service for a proper length of time. Chemical analysis may aid as an indication of the suitability of a brick for some specific requirements; as, for example, a brick high in silica should not be selected for use in places where basic slags are encountered and likewise one high in alumina should not be used in connection with acid slags. For furnace linings it is advisable to use a dense, hard burned brick, and in the arches a close grained brick, not liable to spall or shrink, should be employed. For use around the fire doors, a brick of fairly close grain and one capable of resisting the abrasion of firing tools should be chosen.

In laying fire brick, the thinnest possible joints should be made, at the same time permitting the adjoining bricks to be fully bedded in the mortar so as to avoid unequal stresses due to partial contact. Where it is necessary to line the furnace periodically, the lining should not be bonded throughout with the main setting, but at intervals by headers running into the main brickwork, thus cutting down expense and unnecessary delays when repairs are necessary.

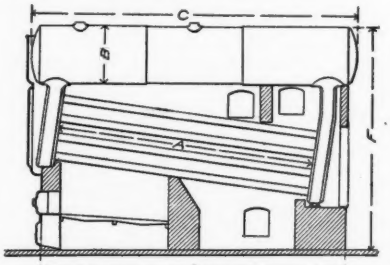
For use in laying firebrick where the temperatures are less than 2200 deg. F., Rutland cement is good, and for temperatures above 2200 deg. F., silica cement may be used with equal results, both these being products of the Rutland Fire Clay Co., of Rutland, Vt. Another good firebrick binder on the market is Holdfast Cement,

MATERIALS REQUIRED FOR SETTINGS OF HORIZONTAL RETURN TUBULAR BOILERS

SIZE OF BOILER		HALF ARCH				FULL FRONT				
Dia. In.	Len. Ft.	Fire Brick	Com. Brick	Bu. Sand	Bu. Lime	Fire Brick	Com. Brick	Bu. Sand	Bu. Lime	Bbl. Fire Clay
30	8	425	4820	52	11	425	5800	70	16	1
32	8	460	5110	54	12	460	6200	72	17	1
32	10	510	5260	60	13	510	6800	79	18	1
36	8	520	5200	59	13	520	6800	75	18	1
36	10	560	5550	65	14	560	7500	85	19	1
36	12	570	6640	70	15	570	6150	89	20	1.25
36	14	650	7700	73	16.5	650	9150	95	22	1.25
36	16	700	8850	76	17	700	10250	103	24	1.25
40	10	575	6000	69	15	575	8150	87	20	1.25
40	12	625	7000	75	16	625	8750	93	21	1.5
40	14	675	7800	78	16.5	675	9700	98	23	1.5
40	16	725	9000	80	17.5	725	10650	106	25	1.5
42	12	650	8000	76	16.5	650	9100	95	22	1.5
42	14	700	8500	78	17.0	700	10000	100	24	1.5
42	16	750	9000	85	18.0	750	11200	108	26	1.5
44	12	655	7120	80	17.0	655	9300	97	22	1.5
44	14	680	8700	82	18.0	680	10500	105	24	1.5
44	16	725	9250	86	19	725	11500	110	26	1.5
44	18	760	10000	92	21	760	12600	117	31	1.5
48	12	730	7460	85	18	730	9250	100	23	1.5
48	14	790	8300	88	18.5	790	11000	108	25	1.5
48	16	850	9260	90	19.5	850	12200	114	27	1.75
48	18	900	10100	97	22	900	13250	120	32	1.75
54	12	800	10000	90	19	800	10900	106	26	1.75
54	14	850	11980	92	20	850	11700	142	27	1.75
54	16	900	12600	98	21	900	13100	120	29	2.00
54	18	950	14000	104	23	950	14150	1270	35	2.00
60	12	810	10500	100	21	810	12000	112	26	2.00
60	14	850	12000	102	22	850	12900	118	28	2.00
60	16	890	13500	106	23	890	14000	126	31	2.00
60	18	950	15000	110	25	950	15000	131	34	2.00
60	20	1000	16000	115	25	1000	14000	143	39	2.00
66	14	900	13000	105	23	900	13750	125	30	2.5
66	16	975	14250	108	24.5	975	14750	132	32	3.5
66	18	1125	15500	113	26.5	1125	16800	140	36	3.5
66	20	1225	16750	118	28.0	1225	16800	148	42	3.0
72	14	1300	13750	108	24.5	1300	14600	130	31	3.0
72	16	1400	15000	110	26.5	1400	15600	138	34	3.0
72	18	1500	16300	115	27.5	1500	16750	146	38	3.0
72	20	1600	17600	120	29	1600	18000	154	44	3.0

made by the Philadelphia Fire Brick Works, of Philadelphia, Pa.; also the H. W. Johns-Manville Co.'s J-M No. 31 High Temperature Cement is satisfactorily used for boiler settings.

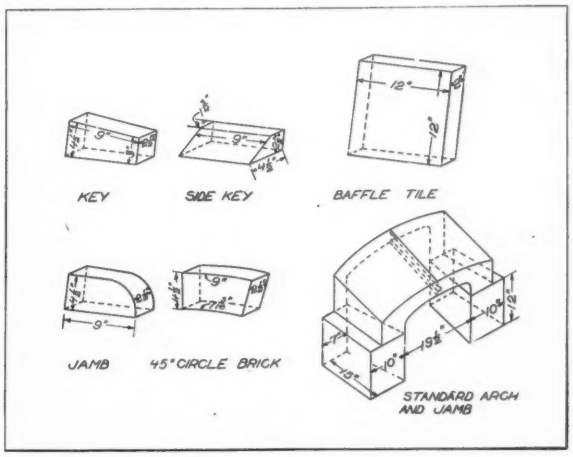
For baffle tiles and ignition arches, none but the highest grade of refractory materials should be used. Owing to the narrow space between the tubes, a shape over 2 in. in thickness cannot be used, and as a large percentage of the losses in a boiler are due to short-circuiting of the furnace gases through these baffle walls, it is advisable to use 2 courses of brick.



TYPICAL HORIZONTAL WATER-TUBE BOILER

The best material adapted for ignition arches is one of the highest grade of refractoriness and not liable to excessive spalling or shrinkage. The Massillon Stone & Fire Brick Co., of Pittsburgh, Pa., and Massillon, Ohio, highly recommends the use of brick made of "Corundite" and fire clay. When common fire brick is used for furnace linings trouble in the form of clinker adhering to the wall will generally be encountered, and the only way to remove this substance is by use of a cold chisel and hammer; but to prevent any trouble of this nature, the Harbison-Walker Refractories Co., of Pittsburgh, Pa., has developed and placed on the market the "Bauxite" brick, deriving its name from Bauxite ore from which it is manufactured and of such a composition as not to be affected by clinker as is the ordinary fire brick.

For furnace linings, boiler-door arches and jambs, many specially prepared forms are on the market. These forms are as a rule considerably larger than ordinary bricks and on account of their shape are not only easier



STANDARD FORMS OF FIRE BRICKS AND BLOCKS

to place but have the advantage of being easily built up into the desired form. The accompanying illustration shows some of the more important of these blocks, such as the key, side key, jamb and circle block. A standard arch and jamb is also shown assembled, which as seen consists of but 4 separate blocks instead of many small bricks, as in the usual form of construction. Above the arch and jamb is a standard size tile used for baffling purposes.

DIMENSIONS OF HORIZONTAL WATER-TUBE BOILERS

Boiler. Horsepower.	No. of Tubes in Width.	No. Tubes in Height.	L'th Tubes in Feet. A	Diam. of Drum. Inches. B	L'th of Drum. Feet. C	Average Weight in Tons.	L'th of Setting Feet. D	Width of Set'g. Feet.	Height of Set'g. Feet.	No. of Common Brick.	No. of Fire Brick.	Diam. of Safety Valve. Inches.	Heating Surface in Square Feet.	Area of Grate. Square Feet.
10	3	4	6	24	10	3	9	4	8.0	7,200	500	2	119	5.21
12	3	4	8	24	12	3.25	11	4	8.5	7,620	740	2	150	6.25
15	3	5	8	24	12	3.5	11	4	9	7,760	750	2	181	7.28
20	3	5	10	24	13	4.25	13	6	9	5,170	980	2	210	8.33
25	4	5	10	30	15	5	15	6	9.5	3,350	1,000	2.5	293	10.67
30	4	5	12	30	17	5.25	15	6	9.5	3,760	1,170	2.5	343	10.67
35	4	6	12	30	17	6	16	5.5	11	4,970	1,510	3	401	12.00
40	4	6	14	30	19	6.5	19	5.5	11	7,460	1,680	3	460	13.33
45	4	7	14	30	19	7	19	6.5	11	8,630	1,410	3.5	526	13.33
50	4	8	14	30	19	7.25	19	6.5	12	8,920	1,540	3.5	593	13.33
60	5	8	14	36	19	8.5	19	6	12.5	9,180	1,600	3.5	735	16.25
70	6	7	16	36	21	10	21	7	12	9,800	1,650	3.5	850	19.17
80	6	8	16	36	21	11	21	7	12.5	10,300	1,738	4	983	19.17
90	6	9	16	36	21	11.5	21	7	13	10,900	1,950	4	1,098	23.00
100	6	9	18	36	24	12	23	7	13.5	12,570	1,970	5	1,118	23.00
110	7	8	18	36	24	12.25	23	7.5	13	12,400	2,000	5	1,265	26.50
120	7	9	18	36	24	12.5	23	7.5	13.5	12,750	2,010	5	1,411	26.50
125	7	9	18	42	24	12.75	23	7.5	14	12,800	2,160	5	1,426	26.50
140	8	9	18	42	24	14	23	8	14	12,830	2,080	5	1,819	30.00
150	12	7	16	36	21	18.25	21	10	12.5	13,160	2,020	4	1,741	36.67
160	9	9	18	48	24	16.75	23	8	14.5	12,960	2,080	5	1,82	38.50
175	12	8	16	36	21	18.75	21	10	13	13,180	2,160	4	1,906	36.67
190	12	9	16	36	21	20.25	21	10	13.5	13,300	2,300	4	2,197	44.00
210	12	9	18	36	24	20.75	23	10	13.5	13,300	2,230	5	2,427	44.00
230	14	9	18	36	24	21.25	23	11.5	13	13,400	2,310	5	2,531	51.00
240	14	9	18	36	24	23.25	23	11.5	13.5	14,000	2,350	5	2,823	51.00
250	14	9	18	42	24	24.25	23	11.5	14	14,000	2,000	5	2,892	51.00

These blocks are made of various materials, such as "Steel Mixture," the product of the McLeod & Henry Co., of Troy, N. Y.

A solid, one-piece boiler door arch or even a whole furnace lining can be built up without the use of forms or molds with plastic fire brick, such as made by the Betson Plastic Fire Brick Co., Rome, N. Y. This substance, which is obtainable in barrels, is quite stiff and

only requires being well pounded into the shape or place desired, forming a tight and perfect fitting, crevice filling, arch or lining. It sets by means of a slow fire in a short time when it becomes hard and may be put into immediate use.

Proportions of Firebox and Combustion Spaces

TO a great degree, the success of a boiler installation depends upon the spaces allowed in the fire box and gas passages. The size of the grate is governed by: First, the capacity of the boiler; second, the kind of fuel and, third, the draft available.

In hand-fired plants using anthracite coal under forced draft, 40 to 50 sq. ft. of heating surface to 1 sq. ft. of grate has been found to give excellent results. Where bituminous coal is burned with natural draft there is variation in the ratio of heating surface to grate surface ranging from 50 to 78, with average 60. For stokers used with natural draft conditions are much as with hand-fired furnaces, and excellent results are obtained with ratios from 50 to 60 to 1 of projected area.

SPACINGS FOR RETURN TUBULAR BOILERS WITH COMBUSTION CHAMBERS

Diameter of Boiler -in.	Bituminous Coal			Anthracite Coal		
	Shell to Grate at rear - in.	Shell to Bridge Wall - in.	Shell to Back Wall - in.	Shell to Grate at rear - in.	Shell to Bridge Wall - in.	Shell to Back Wall - in.
30	22	10	16	20	9	16
36	26	12	16	20	9	16
38	28	13	16	20	9	16
40	28	13	18	22	10	18
42	30	14	18	22	10	18
44	32	14	18	22	10	18
46	32	14	18	22	10	18
48	34	14	18	24	10	18
50	36	15	18	24	10	18
52	36	15	18	24	10	18
54	38	19	20	24	12	20
56	40	20	20	24	12	20
58	42	20	20	24	12	20
60	42	20	24	26	12	24
62	44	20	24	26	12	24
64	46	21	24	26	12	24
66	46	23	24	28	14	24
68	48	24	24	28	14	24
70	50	25	24	28	14	24
72	52	27	26	30	16	26

In many plants boilers are installed with the intention to work them far beyond their rating during peak loads and, if natural draft prove insufficient for this, forced draft with the ratio of 50 to 1 will allow the boiler to work at 300 per cent of its rating for short periods.

If hand-fired, the depth of a furnace should not exceed 6 ft., except under special conditions, as greater depth will make firing difficult, except that small sizes of anthracite coal, which do not give trouble from clinkers, can be fired without great difficulty in furnaces even 8 ft. deep.

Best results are secured from a furnace when it is required to work up to or above its rated capacity; a "lazy" fire is wasteful of fuel; a good working average rate of combustion is 25 lb. of bituminous coal per square foot per hour, on a hand-fired grate, and 19 to 20 lb. of anthracite.

Probably the most important dimension in the boiler setting is the distance from the grate to the heating surface. To secure perfect combustion, gases coming from the coal must not have their temperature lowered below the point of ignition until they are completely united with the oxygen of the air. Coals high in volatile matter require more space here than those with a lower percentage of such constituents.

For return tubular boilers equipped with hand-fired grates the accompanying table gives dimensions which have been used with good results, when the gases pass over the bridge wall into a comparatively large combustion chamber, so that union with the oxygen is completed before all the gas really comes in contact with the heating surfaces.

With water-tube boilers the conditions are different, for after the gases once strike the tubes contact is continuous until they pass out of the setting. Good results are secured in some plants using anthracite coal where the furnace is equipped with an ignition arch and the tubes are 3 ft. from the grates, but in bituminous plants the minimum for best operation seems to be about 8 ft.; this will give smokeless combustion at all loads. In general, the combustion space should never be crowded; ignition arches should be built so as to allow the gases to expand as they are heated without increasing their velocity greatly. No advantage is gained by having the temperature in the furnace higher than that which insures complete combustion. Advantages of low temperatures are less clinker formation, longer life for the furnace walls, greater comfort to the firemen, lower flue gas temperature and higher overall efficiency, provided, of course, that the temperature is lowered by radiation to the heating surface.

The following proportions of air space and iron in the surface of hand-fired grate bars are given by W. W. Christie:

Kind of Fuel	Width, air space, in.	Thickness, iron, in.
Screenings	1/4	3/8
Buckwheat	3/8	3/8
Nut or pea	1/2	1/2
Bituminous or stove	5/8	1/2
Egg	3/4	1/2
Broken	7/8	1/2
Lump	1	1/2
Sawdust	1/4 or 3/8	3/8
Shavings	1/2 or 5/8	1/2

The proportion of air space through the grate surface should be as large as the grade of fuel used will permit. For the finest kind of anthracite, slack, forced draft is generally employed and the per cent of air space runs as low as 10. With larger sizes of coal, the air space is increased and usually runs between 40 and 50 per cent for hand-fired grates. For stokers, the air space is likely to be less than with hand-fired grates to prevent the leakage of coal through the working bars or links. This, however, can only be made as a general statement, as each class of stokers works on a different principle and the proportions are changed accordingly.

Boiler Capacity

ALL parts of a boiler, shell, flues or tubes which are covered with water and exposed to the hot furnace gases are considered as heating surfaces. According to recommendations of the American Society of Mechanical Engineers, the side next to the gases is to be used in figuring the extent of the heating surface, which, in the case of fire tubes is the internal area of the tube and in water-tube boilers the outside area of the tubes.

A boiler horsepower is an arbitrary value, defined as the evaporation of 34.5 lb. of water from and at a temperature of 212 deg. F.

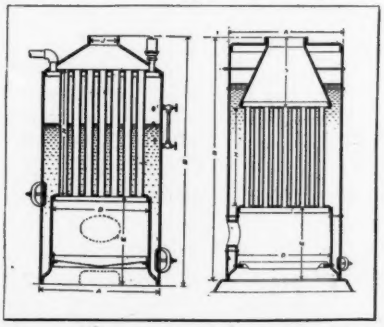
With most boilers it is found that best results are obtainable with an evaporation of from 3 to 3.5 lb. of water from and at 212 deg. F. per sq. ft. of heating surface, which is equivalent to from 12 to 10 sq. ft. per boiler horsepower-hour. The evaporation may be increased by increasing the quantity of the heat, but as a smaller percentage of the heat is utilized, it is done at the expense of efficiency. For maximum economy under average operating conditions, present day practice allows a proportion of 1 sq. ft. of heating surface to every 3.5 lb. of water evaporated from and at 212 deg. F. As a general rule, however, builders of return tubular and vertical fire-tube boilers allow 11 to 12 sq. ft. of heating surface per horsepower, 10 sq. ft. per horsepower for water-tube boilers and 8 sq. ft. per horsepower for Scotch marine boilers. The following table shows approximately the relation between boiler horsepower and heating surface for different ratios of evaporation:

DIMENSIONS OF STANDARD LAP WELDED BOILER TUBES AS GIVEN BY MORRIS TASKER & CO., LTD.

External Diameter	Internal Diameter	Standard Thickness	Internal Circumference	External Circumference	Internal Area		External Area		Length of Tube per Sq.Ft. of Inside Surface	Length of Tube per Sq.Ft. of Outside Surface	Length of Tube per Sq.Ft. of Mean Surface	Weight per Lineal Foot
Inches	Inches	Inches	Inches	Inches	Sq.In.	Sq.Ft.	Sq.In.	Sq.Ft.	Feet.	Feet.	Feet.	Pounds.
1	.856	.072	2.689	3.142	.575	.004	.785	.0055	4.460	3.819	4.139	.708
1¼	1.106	.072	3.474	3.927	.960	.0067	1.227	.0085	3.455	3.056	3.255	.9
1½	1.334	.083	4.191	4.712	1.396	.0097	1.767	.0123	2.863	2.547	2.705	1.25
1¾	1.560	.095	4.901	5.498	1.911	.0133	2.405	.0167	2.448	2.183	2.315	1.665
2	1.804	.098	5.667	6.283	2.556	.0177	3.142	.0218	2.118	1.909	2.013	1.981
2¼	2.054	.098	6.484	7.069	3.314	.0230	3.976	.0276	1.850	1.698	1.774	2.238
2½	2.283	.109	7.172	7.854	4.094	.0284	4.909	.0341	1.675	1.528	1.600	2.755
2¾	2.533	.109	7.957	8.639	5.039	.035	5.940	.0412	1.508	1.390	1.449	3.045
3	2.783	.109	8.743	9.425	6.083	.0422	7.069	.0491	1.373	1.273	1.323	3.335
3¼	3.012	.119	9.462	10.210	7.125	.0495	8.296	.0576	1.268	1.175	1.221	3.958
3½	3.262	.119	10.248	10.995	8.357	.058	9.621	.0668	1.171	1.091	1.131	4.272
3¾	3.512	.119	11.033	11.781	9.687	.0673	11.045	.0767	1.088	1.018	1.053	4.590
4	3.741	.130	11.753	12.566	10.992	.0763	12.566	.0872	1.023	.955	.989	5.32
4½	4.241	.130	13.323	14.137	14.126	.0981	15.904	.1104	.901	.849	.875	6.01
5	4.720	.140	14.818	15.708	17.497	.1215	19.635	.1364	.809	.764	.786	7.226
6	5.699	.151	17.904	18.849	25.509	.1771	28.274	.1963	.670	.637	.653	9.346
7	6.657	.172	20.914	21.991	34.805	.2417	38.484	.2673	.574	.545	.560	12.435
8	7.636	.182	23.989	25.132	45.795	.318	50.265	.3490	.500	.478	.489	15.109
9	8.615	.193	27.055	28.274	58.291	.4048	63.617	.4418	.444	.424	.434	18.002
10	9.573	.214	30.074	31.416	71.975	.4998	78.540	.5454	.399	.382	.391	22.19
11	10.560	.22	33.175	34.557	87.479	.6075	95.033	.6601	.361	.347	.354	25.489
12	11.542	.229	36.26	37.699	103.749	.7205	113.097	.7854	.330	.318	.324	28.516
13	12.524	.238	39.345	40.840	123.187	.8554	132.732	.9213	.305	.293	.299	32.208
14	13.504	.248	42.414	43.982	143.189	.9943	153.938	1.069	.282	.272	.277	36.271
15	14.482	.259	45.496	47.124	164.718	1.1438	176.715	1.2272	.263	.254	.258	40.612
16	15.458	.271	48.562	50.265	187.667	1.3032	201.062	1.188	.247	.238	.242	45.199
17	16.432	.284	51.662	53.407	212.227	1.4738	226.980	1.5762	.232	.224	.228	49.902
18	17.416	.292	54.714	56.548	238.224	1.6543	254.469	1.7671	.219	.212	.215	54.816
19	18.400	.3	57.805	59.690	265.903	1.8465	283.529	1.969	.207	.200	.203	59.479
20	19.360	.32	60.821	62.832	294.373	2.0443	314.159	2.1817	.197	.190	.193	66.765
21	20.320	.34	63.837	65.973	324.311	2.2522	346.361	2.4055	.188	.181	.184	73.404

EVAPORATION FROM AND AT 212 DEG. F. PER SQUARE FOOT PER HOUR

2	2.5	3.0	3.5	4	5	6	7	8	9	10
SQUARE FEET HEATING SURFACE REQUIRED PER HORSEPOWER										
17.3	13.8	11.5	9.8	8.6	6.8	5.8	4.9	4.3	3.8	3.5



LEFT; VERTICAL TUBULAR BOILER. RIGHT; VERTICAL BOILER WITH SUBMERGED TUBES

CALCULATION OF HEATING SURFACE

IN ORDER to find the heating surface of vertical tubular boilers, multiply the circumference of the fire box (in inches) by its height above the grate; multiply the circumference of a tube by its length and by the number of tubes, and to these 2 products add the area of the lower tube sheet; from this sum subtract the area of all the tubes, and divide by 144; the quotient is the

DIMENSIONS OF VERTICAL TUBULAR BOILERS

Horsepower	Shell		Furnace		Exposed Tubes, 2 In.				Submerged Tubes 2 In.			
	Dia. A	Ht. B	Dia. D	Ht. E	Len. H	Number	Heating Surface	Dia. of Stack J	Len. H	Number	Heating Surface	Comb. Ch. Ht. J
	In.	Ft.	In.	In.	In.		Sq.Ft.	In.	In.		Sq.Ft.	In.
5	24	5	20	24	36	31	60	12	30	31	52	18
10	30	6	25	27	45	55	121	14	33	55	98	18
15	36	6½	31	28	51	77	189	15	39	77	155	18
20	36	8	31	28	69	77	250	15	39	109	215	24
25	42	7½	37	30	60	109	307	18	45	109	244	24
30	42	8½	37	30	72	109	364	18	57	109	301	24
35	42	9½	37	30	84	109	422	20	51	149	370	27
40	48	8½	43	32	72	149	496	24	57	149	409	27
45	48	9	43	32	78	149	535	24	63	149	443	27
50	48	10	43	30	90	149	613	24	54	201	518	30
60	54	9	48	30	78	201	718	28	66	201	623	30

number of square feet of heating surface. For finding the heating surface of horizontal tubular boilers, multiply ½ of the circumference of the shell by its length; multiply the circumference of a tube by its length and by the number of tubes; to the sum of these products add ⅔ of the area of both tube-sheets; from this sum subtract twice the combined area of all the tubes; divide the remainder by 144 to obtain the result in square feet.

STEAM SPACE IN HORIZONTAL TUBULAR BOILERS PER FOOT OF LENGTH

Dist. of Water Levels from top of Shells	Diameter of Shell in Inches.												
	36	40	42	44	48	52	54	56	60	64	66	68	72
1/8 of Diam.	0.5094	0.6214	0.6367	0.7618	0.9056	1.060	1.146	1.233	1.415	1.607	1.712	1.819	2.037
3-16	0.9135	1.114	1.243	1.366	1.624	1.902	2.055	2.212	2.537	2.882	3.070	3.262	3.654
1-4	1.381	1.706	1.880	2.066	2.456	2.876	3.108	3.346	3.837	4.359	4.643	4.933	5.526
5-16	1.882	2.297	2.562	2.815	3.347	4.046	4.236	4.560	5.410	5.941	6.328	6.723	7.531
1-8	2.059	2.535	2.802	3.063	3.650	4.287	4.633	4.767	5.720	6.497	6.921	7.328	8.236
3-8	2.421	2.953	3.295	3.620	4.304	5.041	5.447	5.839	6.725	7.639	8.137	8.616	9.684
7-16	2.968	3.621	4.040	4.439	5.276	6.180	6.678	7.189	8.245	9.366	9.976	10.599	11.872
1-2	3.531	4.310	4.810	5.284	6.281	7.359	7.951	8.575	9.817	11.162	11.878	12.578	14.137

To find the square feet of heating surface in tubes; multiply the number of tubes by the diameter of a tube in inches; by its length in feet and by 3.1416 ÷ 12.

Heating Surface of Water-Tube Boilers

For water-tube boilers the heating surface consists of the external area of the tubes plus that area of the steam drum or drums exposed to the hot gases which is usually taken as the area of the lower half of the drum or drums. In some types of boilers, header and mud drum surfaces are exposed to hot gases, but usually in such a manner that they are of little value as heating surfaces.

In computing this heating surface, the external circumference of the tube in feet should be multiplied by its length in feet times the number of tubes, to which should be added the products obtained by multiplying the length of each shell in feet by one-half its circumference in feet.

In calculating the heating surface of a vertical water-tube boiler consisting of vertical top and bottom drums connected by vertical tubes, the bottom drum may be neglected and to the combined external area of all the tubes add the area of the bottom of the upper shell minus the combined areas of the tube holes plus the area, if any, of the upper shell which has contact with hot gases.

Effect of Circulation on Capacity

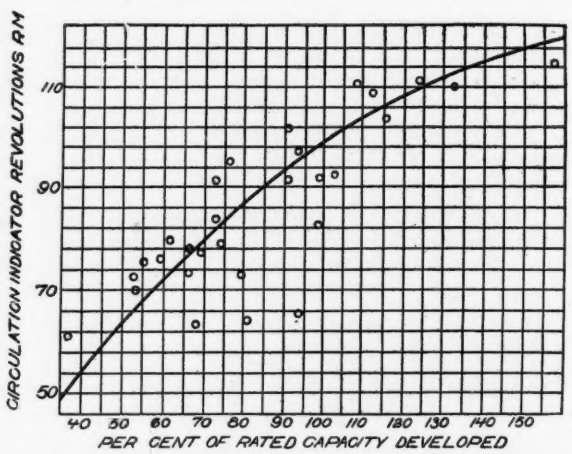
In the curve herewith are shown results obtained by the U. S. Geological Survey while testing a boiler to determine the relation between the circulation of water and the capacity of the boiler. The values given were obtained by counting the total number of revolutions of a circulation indicator for each half hour period, and by calculating the percentages of the rated horsepower developed by the boiler for each such period. An important fact brought out by this curve is that the circulation rapidly drops behind the amount of steam made, especially at high rates of working. This, therefore, indicates that, if the circulation of a boiler can be increased, the capacity may also be rapidly increased.

Forcing Boilers

Present day practice seems to demand the forcing of boilers, especially during peak load periods. Even though, as previously stated, forcing may be done at the expense of economy and efficiency, it is found in the greater number of cases to be more advisable to force the boilers and thereby tide over heavy loads in this manner than to install additional units and allow them to remain idle the greater part of the time.

Steam is usually allowed to occupy about ⅓ the volume of the boiler. This is the volume of the shell minus the volume of the tubes.

Because of the varying shapes and forms of boilers upon the market, the varying cross-sectional areas of gas passages, and the different volumes of settings and different modes of gas travel, every boiler has its special characteristic in ability to transmit heat, upon which forcing depends. It may, however, be said that in order to force a boiler, its entire heating surface must be kept clean and free of all deposits of any nature. A



CURVE SHOWING THE RELATION BETWEEN THE CAPACITY OF A BOILER AND THE CIRCULATION OF WATER

boiler for high rates of driving must have a rapid, uniform and predetermined circulation of water. A scrubbing action must be established on the water side so that as rapidly as the steam globules are formed, they may be swept away and replaced by rapidly moving water. Steam must not be allowed to accumulate on the gas swept surface. The specific heat of steam being approximately only ½ that of water, precludes its accumulation at a point where high-temperature gases bathe the heating surface. The steam must be replaced

by the water as quickly as it is formed, so that it is the water presenting itself to the hot gases for abstraction of the heat from the gases and not steam. While up to the present, little has been done along this line, it has been proposed as an aid to forcing, to place a circulator in the boiler so that a rapid circulation could be maintained.

In addition to keeping the internal heating surfaces clean, it is absolutely necessary to remove all accumulation of soot and dirt from those surfaces next to the hot gases.

Strength

DUE to the stress placed upon it by the pressure of the steam, the material used in boiler construction must possess a high degree of tensile strength; and also sufficient ductility to withstand the expansion and contraction brought about by the alternate heating and cooling.

For practically all high-pressure boilers, the material now used is mild steel, whose high strength permits of using comparatively thin plates, which transmit heat readily.

If wrought iron is used for plates, it should have a tensile strength of from 50,000 to 60,000 lb. per sq. in. and an elongation of from 10 to 15 per cent in a length of 8 in. The elastic limit should not be less than 27,000 lb. For wrought-iron rivets the tensile strength should be 50,000 lb. and the shearing strength 40,000 lb. per sq. in. They should bend cold without fracture, should have an elongation of 18 per cent in 8 in. of length and heads should be hammered to ⅛ in. thickness flat without fraying at the edges. All wrought iron should be able to show a contraction of 40 per cent at the fracture.

Steel

Steel used for shells should have a tensile strength of from 60,000 to 75,000 lb. per sq. in., or if it is to be used for heads where it must be flanged out, a strength of 52,000 to 60,000 lb. per sq. in. is required. The elongation for shell material should be 20 per cent, 25 per cent for heads and 27 per cent for stays. Contraction for plates of a thickness up to ½ in. should be 50 per cent; for ½ in. to ¾ in., 45 per cent; and over ¾ in., 40 per cent.

Tests

For testing plates, a piece is taken from the side thereof and tested for tensile strength. The test piece is cut the full thickness of the plate and if 5/16 in. or less in thickness, the width at the center is made 1 in., while if it is over 5/16 in. in thickness, the width at the center is made such that the area of the cross section will be approximately 0.4 sq. in.; not less than 0.35 sq. in.

Tensile strength is found by pulling the piece apart in a testing machine and dividing the pull necessary to break the piece by the cross-sectional area of the smallest section before testing, to get the strength per square inch.

Ductility or contraction is determined by subtracting the area of cross-section at the point of fracture after breaking, from the area at the same point before testing, and dividing the remainder by the cross-sectional area before testing.

For an elongation test, a second test piece must be provided and on this a length of 8 in. laid off so as to come on the length between the jaws of the testing ma-

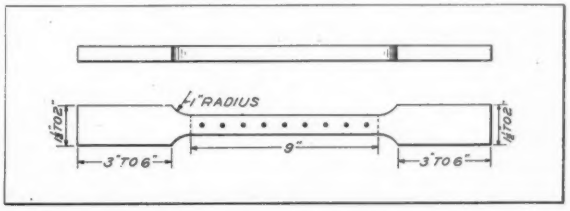


FIG. 1. COUPON FOR ELONGATION TEST

chine. The specimen is then pulled apart and the final length of this original 8 in. length measured, the percentage of elongation being equal to the difference between the final and the original lengths divided by 8.

Shell Calculations

To determine the thickness of shell required for longitudinal stress, we will consider the accompanying illustration to represent a section of a cylinder having a length of 1 in.; then pressure per square inch times diameter in inches equals twice the tensile strength times the thickness times the joint efficiency, divided by the factor of safety. The safe pressure is, then, equal to the last term of the equality, divided by the

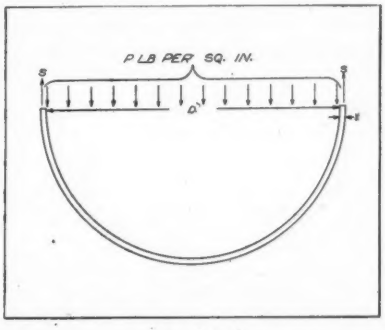


FIG. 2. DIRECTION OF FORCES ACTING TO TEAR CYLINDER APART LONGITUDINALLY RESISTED BY STRESS IN METAL

diameter. And the safe thickness for a given pressure equals the factor of safety times pressure times diameter, divided by twice the tensile strength times joint efficiency.*

In order to find the thickness of the material to resist stress along the girth, multiply the area of the head by the working pressure; this equals the thickness of the material multiplied by the circumference of the shell, by the tensile strength of the material and by the joint efficiency, and divided by the factor of safety. We then have: Safe thickness will equal area of head times working pressure times factor of safety, divided by (circumference of shell times tensile strength times joint efficiency).

*In the form of equations, if p = pressure, D = diameter, S = tensile strength t = thickness, f = factor of safety and e = joint efficiency,
pD = 2Ste ÷ f: p = 2Ste ÷ fD; t = pDf ÷ 2Se.

If these rules are worked out, it will be found that thickness required for longitudinal stress is twice that required for girth stress.†

Riveted Joints

TYPES of riveted boiler joints have become well standardized during the progress in the manufacture of boilers and those in common use are as follows:

Single riveted lap joint.

Double riveted lap joint.

Double riveted butt and double-strap joint, in which the pitch of rivets in the outer row is twice the pitch of rivets in the second row.

Triple riveted butt and double-strap joint, in which the pitch of rivets in the outer row is twice the pitch of rivets in the second and inner rows.

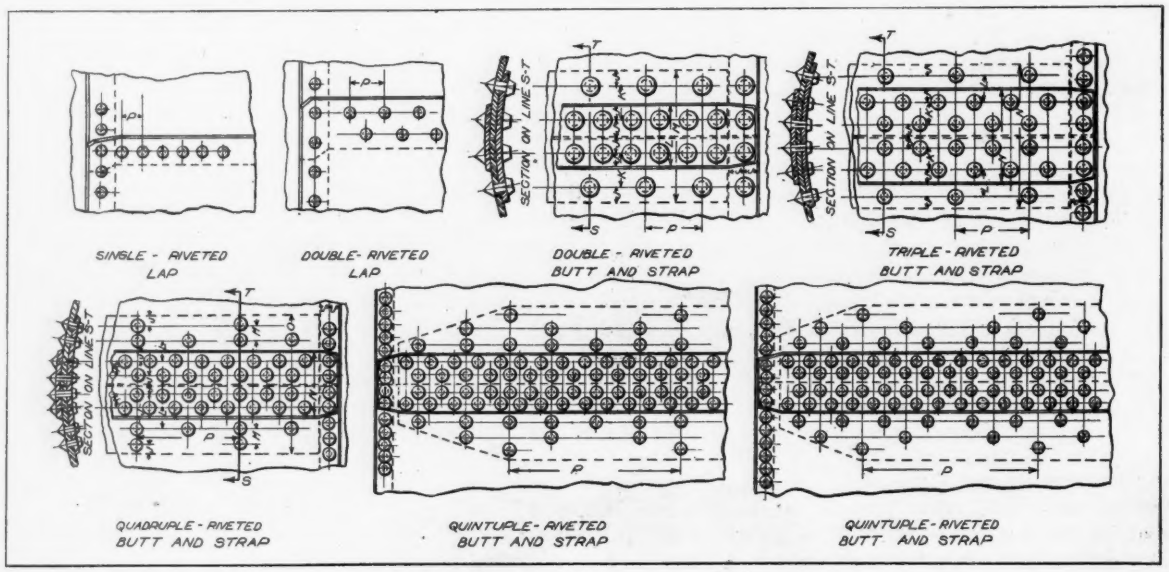

SINGLE - RIVETED LAP
DOUBLE- RIVETED LAP
DOUBLE - RIVETED BUTT AND STRAP
TRIPLE - RIVETED BUTT AND STRAP
QUADRUPLE - RIVETED BUTT AND STRAP
QUINTUPLE - RIVETED BUTT AND STRAP
QUINTUPLE - RIVETED BUTT AND STRAP
SECTION ON LINE S-T

FIG. 1. STANDARD TYPES OF RIVETED BOILER JOINTS

Quadruple riveted butt and double-strap joint, in which the pitch of rivets in the outer row is twice the pitch of rivets in the second row and 4 times the pitch of rivets in the third and inner rows.

Quintuple riveted butt and double-strap joint, in which the pitch of rivets in the outer row is twice the pitch of rivets in the second row, 4 times the pitch of rivets in the third row, and 8 times the pitch of rivets in the fourth and fifth rows.

All these types of joints are illustrated herewith. The quintuple riveted joint permits of 2 arrangements of rivets and although seldom used at present the pressures carried on boilers is continually increasing and the need for a stronger joint is met by this type.

Calculation of the strength of a joint requires first a careful analysis to determine the possible places where failure can take place, as the weakest part represents the strength of the joint. The efficiency of a joint is the ratio which the strength of a unit length of the joint bears to the strength of the solid plate of the same length.*

The accompanying table gives the most practical pitch of rivets and the joint efficiency obtainable with given thickness of plate and butt strap, and size rivets for the various types of joints in most common use on boilers worked out from the formulas given above. The proper spacing of the rows of rivets and the widths of the butt straps are shown by the accompanying curves with letters referring to the illustrations of the joints.

All boiler joints should be carefully calked with a round nose tool, the calking edges being beveled wherever possible. The tool should not be allowed to strike the shell plate as it is apt to mar the metal and cause a weak spot.

Rivets used are made of extra soft open hearth steel, the tensile strength of which is between 45,000 and

†Using same symbols as before, and A = area of head; C = circumference of shell: $pA = tCSe \div f$: $t = pAf \div CSe$: $A = 3.1416D^2 \div 4$: $C = 3.1416D$: hence $t = 3.1416\ pD^2f \div 4 \times 3.1416D\ Se$: and cancelling common terms, $t = pDf \div 4Se$.

*In the formulas given below the following symbols are used:
T. S. = tensile strength stamped on plate, in pounds per square inch.
t = thickness of plate in inches.
b = thickness of butt strap in inches.
P = pitch of rivets, in inches, on row having greatest pitch.
d = diameter of rivet after driving, in inches, = diameter of rivet hole.
a = cross-sectional area of rivet in square inches, after driving.
s = strength of rivet in single shear, based on iron with a shearing strength of 38,000 lb. per sq. in. and steel 42,000.
S = strength of rivet in double shear, based on 70,000 lb. per sq. in. for iron, and 78,000 lb. for steel.
c = crushing strength of mild steel, taken as 95,000 lb. per sq. in.
n = number of rivets in single shear in a unit of length of joint.
N = number of rivets in double shear in a unit of length of joint.
For the single rivet lap joint the necessary calculations are:
A Strength of solid joint = P × t × T. S.
B Strength of plate between rivet holes = (P − d) t × T. S.
C Shearing strength of 1 rivet in single shear = n × s × a.
D Crushing strength of plate in front of 1 rivet = d × t × c.
The efficiency of the joint is found by dividing B, C or D (which ever is the least) by A.
In double riveted lap joints the distance between the rows should be about 70 per cent of the pitch, this distance being called back pitch. The calculations for this type of joint are:
A Strength of solid plate = P × t × T. S.
B Strength of plate between rivet holes = (P − d) t × T. S.
C Shearing strength of 2 rivets in single shear = n × s × a.
D Crushing strength of plate in front of 2 rivets = n × d × t × c.
For the butt and double-strap joint double riveted the formulas are:
A Strength of solid plate = P × t × T. S.
B Strength of plate between rivet holes in outer row = (P − d) × T. S.

55,000 lb. per sq. in., and the shearing strength is taken as 42,000 in single and 78,000 lb. in double shear per square inch of cross-section. The size of rivets is such that after being driven they fill the hole completely and form a head equal in strength to the body of the rivet. Before driving, they are never more than 1/16 in. less in diameter than the holes. The sizes of holes for the various sizes of plates are shown in the table.

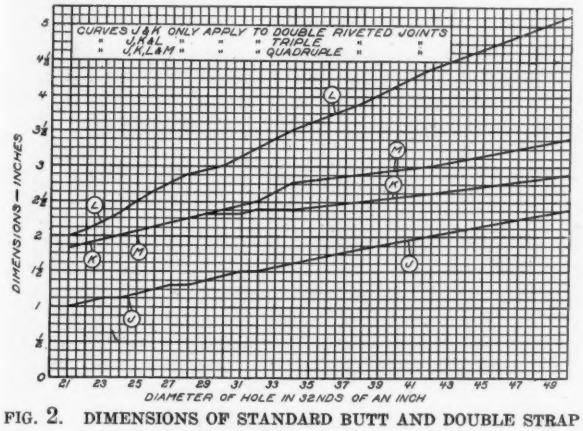

CURVES J & K ONLY APPLY TO DOUBLE RIVETED JOINTS
" J, K & L " " " TRIPLE " " "
" J, K, L & M " " " QUADRUPLE " " "
DIMENSIONS — INCHES
DIAMETER OF HOLE IN 32NDS OF AN INCH

FIG. 2. DIMENSIONS OF STANDARD BUTT AND DOUBLE STRAP JOINTS; LETTERS REFER TO FIG. 1

Owing to the tearing effect upon the metal in punching a hole, the rivet holes for boiler joints should be drilled full size with butt straps and heads bolted in place, or they may be punched not to exceed ¼ in. less in diameter than the finished hole, when the plate is thicker than 5/16 in., and ⅛ in. less in diameter than the finished hole, when the plate does not exceed 5/16 in. in thickness, and then reamed to size with plates, butt straps and heads in place.

C Shearing strength of 2 rivets in double shear plus shearing strength of 1 rivet in single shear = $N \times S \times a + n \times s \times a$.

D Strength of plate between rivet holes in second row, plus shearing strength of 1 rivet in single shear in the outer row = $(P - 2d)\, t \times T.S. + n \times s \times a$.

E Strength of plate between rivet holes in the second row, plus the crushing strength of the butt strap in front of 1 rivet in the outer row = $(P - 2d)\, t \times T.S. + d \times b \times c$.

F Crushing strength of plate in front of 2 rivets plus crushing strength of butt strap in front of one rivet = $N \times d \times t \times c + n \times d \times b \times c$.

G Crushing strength of plate in front of 2 rivets plus the shearing strength of 1 rivet in single shear = $N \times d \times t \times c + n \times s \times a$.

For the triple riveted butt and double-strap joint the formulas are:

A Strength of solid plate = $P \times t \times T.S.$

B Strength of plate between rivet holes in outer row = $(P - d)\, t \times T.S.$

C Shearing strength of 4 rivets in double shear, plus shearing strength of 1 rivet in single shear = $N \times S \times a + n \times s \times a$.

D Strength of plate between rivet holes in second row, plus shearing strength of 1 rivet in single shear in outer row = $(P - 2d)\, t \times T.S. + n \times s \times a$.

E Strength of plate between rivet holes in the second row plus the crushing strength of butt strap in front of 1 rivet in the outer row = $(P - 2d)\, t \times T.S. + d \times b \times c$.

F Crushing strength of plate in front of 4 rivets, plus crushing strength of butt strap in front of 1 rivet = $N \times d \times t \times c + n \times d \times b \times c$.

G Crushing strength of plate in front of 4 rivets plush shearing strength of 1 rivet in single shear = $N \times d \times t \times c + n \times s \times a$.

For the quadruple riveted butt and double-strap joint the formulas are:

A Strength of solid plate = $P \times t \times T.S.$

B Strength of plate between rivet holes in outer row = $(P - d)\, t \times T.S.$

C Shearing strength of 8 rivets in double shear, plus shearing strength of 3 rivets in single shear = $N \times S \times a + n \times s \times a$.

D Strength of plate between rivet holes in second row, plus shearing strength of 1 rivet in single shear in the outer row = $(P - 2d)\, t \times T.S. + n \times s \times a$.

E Strength of plate between rivet holes in third row, plus the shearing strength of 2 rivets in the second row in single shear and 1 rivet in single shear in the outer row = $(P - 4d)\, t \times T.S. + n \times s \times a$.

PITCH AND EFFICIENCY OF STANDARD BUTT AND DOUBLE STRAP JOINTS

THICKNESS OF PLATE	THICKNESS OF INSIDE BUTT STRAP	DIAMETER OF RIVET HOLES	DOUBLE RIVETED T.S. 55000		DOUBLE RIVETED T.S. 58000		TRIPLE RIVETED T.S. 55000		TRIPLE RIVETED T.S. 58000		QUADRUPLE RIVETED T.S. 55000		QUADRUPLE RIVETED T.S. 58000	
			MOST DESIRABLE PITCH OF RIVETS IN OUTER ROW	EFFICIENCY OF JOINT	MOST DESIRABLE PITCH OF RIVETS IN OUTER ROW	EFFICIENCY OF JOINT	MOST DESIRABLE PITCH OF RIVETS IN OUTER ROW	EFFICIENCY OF JOINT	MOST DESIRABLE PITCH OF RIVETS IN OUTER ROW	EFFICIENCY OF JOINT	MOST DESIRABLE PITCH OF RIVETS IN OUTER ROW	EFFICIENCY OF JOINT	MOST DESIRABLE PITCH OF RIVETS IN OUTER ROW	EFFICIENCY OF JOINT
¼	¼	13/32	3 3/16	83.3	3 1/4	82.5	6 3/16	89.3	5 7/16	88.9				
		15/32	4 3/16	83.5	4	82.6	6 1/2	89.4		89.0				
		17/32	4 11/16	83.6	4 1/4	83.0								
		19/32	4 13/16	83.7	4 1/8	83.0								
5/16	¼	13/32	3 7/16	82.7	3 5/16	81.9	6 5/16	89.1	5 7/16	88.7				
		15/32	4 1/16	83.0	3 7/8	82.2	6 7/16	89.3	5 7/16	88.4				
		17/32	4 5/16	83.1	4 1/8	82.4								
		19/32	4 1/2	83.1	4 1/4	82.3								
3/8	¼	13/32					6	89.0	5 7/16	88.4				
		15/32	4 3/16	82.9	4	82.0	6 1/4	89.0	6	88.5				
		17/32	4 3/8	82.8	4 3/16	82.0	6 5/16	89.1	5 13/16	88.6				
		19/32					6 7/16	88.7	5 15/16	88.6				
7/16	¼	13/32	4 3/16	82.6	4 1/16	81.6	7 1/16	89.2	6 1/16	88.6				
		15/32	4 3/16	82.7	4 1/8	81.9	7 1/16	89.1	7 1/16	88.6				
		17/32	4 5/16	82.6	4	82.0	6 15/16	89.1	6 1/16	88.7				
		19/32	4 5/16	82.8	4 1/16	82.0	7	89.2	6 1/16	88.7				
	¼ OR ⅜	13/32	4 5/16	83.1	4 1/16	82.3	7 3/16	89.3	7	88.8				
		15/32	4 7/16	83.3	4 1/16	82.4	7 1/16	89.1	7 1/16	88.8				
1/2	¼	13/32					5 7/16	88.9	5 7/16	88.3				
		15/32					6 1/16	88.7	5 7/16	88.4				
		17/32	4 1/16	82.3	3 15/16	81.5	6 9/16	89.0	6 1/16	88.5				
		19/32	4 1/16	82.3	4 1/16	81.5	6 5/16	88.8	6 1/16	88.4				
		21/32	4 3/16	82.3	4 1/16	81.6	7 1/16	89.0	6 1/16	88.5				
	¼ OR ⅜	13/32	4 3/16	82.4	4 1/16	81.6	7 3/16	88.6	7 1/16	88.4				
		15/32	4 1/16	82.3	3 15/16	81.5	6 15/16	89.0	6 1/16	88.5				
		17/32	4 1/16	82.6	4 1/16	81.6	6 15/16	88.8	6 1/16	88.5				
		19/32	4 3/16	82.6	4 1/16	81.6	7 1/16	89.1	6 1/16	88.6				
		21/32	4 1/16	82.6	4 1/16	81.6	7 1/16	89.1	7 1/16	88.6				
9/16	5/16	13/32					6 1/2	88.9	6 3/16	88.3	13 3/8	94.5	12 3/8	94.1
		15/32					6 1/16	88.7	6 1/16	88.4	13 3/16	94.5	13 1/8	94.2
		17/32	4 3/16	82.3	4 1/16	81.6	7 1/16	89.0	6 1/16	88.5	14 3/16	94.5	13 1/8	94.3
		19/32	4 1/16	82.4	4 1/16	81.6	7 1/16	88.8	7 1/16	88.5	15	94.5	14 3/16	94.3
		21/32	4 1/16	82.6	4 1/16	82.0								
		23/32	4 3/16	82.6	4 1/16	82.0								
		25/32	5 1/16	82.8	4 1/16	82.0								
		27/32					7 3/16	89.1	7 1/16	88.6	15 3/8	94.6	15 1/16	94.4
		29/32					7 1/16	89.1	7 1/16	88.7	15 7/8	94.5	15 3/16	94.4
5/8	5/16	13/32	4 3/8	82.1	4 3/16	81.3	7 1/16	88.9	6 15/16	88.4	14 1/16	94.5	13 1/16	94.2
		15/32	4 3/16	82.1	4 1/16	81.4	7 1/16	88.9	7 1/16	88.4	14 7/16	94.5	14 1/16	94.2
		17/32	4 3/16	82.4	4 1/16	81.5								
		19/32	5	82.5	4 1/16	81.6								
		21/32					7 1/16	89.0	7 1/16	88.5	15 7/8	94.6	14 15/16	94.3
		23/32					7 1/16	88.7	7 1/16	88.5	16	94.5	15 1/16	94.3
11/16	⅜	13/32	4 1/16	82.0	4 1/16	81.2	7 1/16	88.9	7 1/16	88.3	15 7/16	94.5	14 7/16	94.2
		15/32	4 3/16	82.2	4 1/16	81.3	7 1/16	88.7	7 1/16	88.4	16	94.5	15 1/16	94.2
		17/32	5 1/16	82.3	4 3/16	81.5	8 1/16	89.0	7 1/16	88.5	16 1/16	94.5	15 1/16	94.2
		19/32	5 1/16	82.3	5 1/16	81.7	8 1/16	89.0	8 1/16	88.5	16 1/16	94.3	16 1/16	94.3
3/4	⅜	13/32	5 1/16	82.1	4 1/16	81.4	8 1/16	88.9	7 1/16	88.4	16 3/16	94.5	15 1/16	94.2
		15/32	5 1/16	82.1	5 1/16	81.4	8 1/16	88.8	8 1/16	88.4	16 3/16	94.4	16 1/16	94.2
13/16	⅜	13/32	5	81.8	4 15/16	81.1	8 1/16	88.8	7 15/16	88.3	16 3/16	94.4	15 1/16	94.1
		15/32	5 1/16	81.9	5	81.2	8 1/16	88.8	8 1/16	88.3	16 1/16	94.3	16 1/16	94.1
		17/32	5 1/16	82.1	5 1/16	81.3	8 1/16	88.8	8 1/16	88.4	17 1/16	94.4	16 1/16	94.2
		19/32	5 1/16	82.2	5 1/16	81.3	8 1/16	88.4	8 1/16	88.4	17 1/16	94.2	17 1/16	94.2
7/8	⅜	13/32					8 1/16	88.7	7 15/16	87.9	16 1/16	94.3	15 1/16	93.6
		15/32					8 1/16	88.6	8	88.2	16 1/16	94.3	16	94.1
		17/32					8 1/16	88.5	8 1/16	88.3	17 1/16	94.4	16 1/16	94.1
		19/32					8 1/16	88.3	8 1/16	88.3	17 1/16	94.2	17 1/16	94.2
		21/32					8 1/16	88.3	8 1/16	88.3	17 1/16	94.2	17 1/16	94.2
		23/32					9	88.2	9	88.2	16	94.0	16	94.0
15/16	⅜	13/32					8 1/16	88.7	8 1/16	88.0	17 1/16	94.3	16 1/16	93.7
		15/32					8 1/16	88.6	8 1/16	88.3	16	94.1	17 1/16	94.1
		17/32					8 1/16	88.5	8 1/16	88.3	17 1/16	94.1	17 1/16	94.1
		19/32					9	88.2	9	88.2	16	94.0	16	94.0
1	⅜	13/32					8 1/16	88.5	8 1/16	87.4	17 1/16	94.0	16 1/16	92.6
		15/32					8 1/16	88.5	8 1/16	87.7	17 1/16	94.2	17	93.3
		17/32					9	88.5	8 1/16	88.1	16	94.2	17 1/16	93.9
		19/32					9	88.2	9	88.2	16	94.0	16	94.0
1 1/16	⅜	15/32					9	88.4	8 15/16	87.5	16	94.0	17 1/16	93.0
		17/32					9	88.2	9	87.6	16	94.0	16	93.5
1 1/8	⅜	15/32					9	87.6	8 15/16	87.0	16	93.2	17 1/16	92.2
		17/32					9	87.8	9	87.2	16	93.5	16	92.6
1 1/16	⅜ OR ½	15/32					9 1/16	87.6	9	86.7	15 1/2	92.9	16	91.9
		17/32					9 1/16	87.1	9 1/16	86.9	15 1/2	93.5	16 1/2	93.2
1 3/16	⅜ OR ½	15/32					9 1/16	86.9	8 15/16	85.9	15 1/4	92.1	17 1/2	91.0
		17/32					9 1/16	87.0	9 1/16	86.3	15 1/2	93.4	15 1/2	92.4
1 1/4	½	15/32					8 15/16	86.1	8 7/16	84.9	17 3/8	91.2	16 1/8	90.0
		17/32					8 15/16	86.0	9 1/16	86.2	20	93.1	20	92.2
		19/32					9 1/16	86.1	9 1/16	86.1	20	93.4	20	93.3
1 5/16	½ OR ⅝	15/32					10	87.0	10	86.5	20	92.4	20	91.6
		17/32					10	86.9	10	86.2	20	93.5	20	92.5
1 3/8	½ OR ⅝	15/32					10	86.6	9 15/16	85.6	20	91.8	19 3/8	90.7
		17/32					10	86.4	10	85.8	20	92.8	20	91.8
1 7/16	½ OR ⅝	15/32					9 7/8	86.0	9 3/8	84.8	19 3/8	91.1	18 3/4	89.8
		17/32					10	85.9	10	85.3	20	92.1	20	91.1
1 1/2	½ OR ⅝	15/32					9 7/8	85.1	9 3/8	84.0	19	90.2	18 1/8	89.0
		17/32					10	85.5	10	84.9	20	91.4	20	90.5
		19/32					10	85.4	10	84.6	20	92.4	20	91.4
1 5/8	⅝ OR ¾	15/32					9 1/4	84.4	8 7/8	83.3	18 1/8	89.4	17 1/8	88.2
		17/32					10	85.1	10	84.5	20 1/8	91.0	20 1/8	90.2
		19/32					10	84.9	10	84.2	20 1/8	91.9	20 1/8	90.9
1 11/16	⅝ OR ¾	15/32					8 15/16	83.7	8 7/16	82.5	18 1/8	88.7	17 1/8	87.4
		17/32					10 1/16	85.1	10 1/16	84.5	20 1/8	90.5	20 1/8	89.6
		19/32					10 1/16	84.9	10 1/16	84.1	20 1/8	91.3	20 1/8	90.2
1 3/4	⅝ OR ¾	17/32					10 1/8	85.1	10 1/8	84.0	21	90.2	20 1/4	89.0
		19/32					10 1/8	84.8	10 1/8	84.1	21	90.8	21	89.9
1	¾	17/32					10 1/4	84.4	9 1/8	83.3	20 1/8	89.5	19 1/4	88.3
		19/32					10 1/8	84.4	10 1/8	83.6	21	90.3	21	89.4
1 1/16	¾	17/32					9 1/8	83.0	9 1/8	81.8	19 1/2	88.0	19 1/4	86.7
		19/32					10 1/8	83.7	10 1/8	83.1	22	89.7	22	88.9
1 1/8	¾ OR ⅞	17/32					9 1/8	81.6	9	80.5	18 1/4	86.6	18	85.3
		19/32					10 1/8	83.1	10 1/8	82.3	22	88.6	21 1/4	87.6
		21/32					10 1/8	82.8	10 1/8	81.9	22	89.3	22	88.4
1 3/16	¾ OR ⅞	17/32					10 1/8	82.7	10 1/8	81.3	21 1/4	87.6	20 1/4	86.2
		19/32					11	82.8	11	82.2	22	88.4	22	87.5
1 1/4	⅞	17/32					10 1/8	81.3	9 3/4	80.1	20 1/2	86.2	19 3/4	85.0
		19/32					11 1/4	82.6	11 1/4	82.1	22 1/2	87.6	22 1/2	87.0
1 5/16	⅞ OR 1	17/32					9 1/8	80.2	9 1/8	79.1	19 1/4	85.2	19	83.8
		19/32					11 1/8	82.3	10 1/8	80.9	22 1/4	87.2	21 1/4	85.6
1 3/8	⅞ OR 1	17/32					9 1/8	79.2	9 1/8	77.8	19	83.9	18 1/4	82.5
		19/32					11	81.6	10 1/8	80.0	22	86.1	21 1/4	84.6
1 7/16	⅞ OR 1	17/32					9 1/4	78.6	8 7/8	76.6	19 1/8	82.9	17 3/4	81.4
		19/32					11 3/8	80.1	10 1/8	78.5	21 1/4	84.3	20 1/8	83.0
1 1/2	1 OR 1 1/8	17/32					9	77.2	8 7/8	75.7	18	81.6	17 3/4	80.2
		19/32					10 3/8	79.2	10	78.4	20 1/4	83.9	20	82.8
		21/32					11	79.6	11	79.1	22	84.8	22	84.0
1 9/16	1 OR 1 1/8	17/32									20	82.6	19 1/4	81.3
		19/32									22 1/4	84.7	22	83.4
1 5/8	1 1/16	17/32									19 1/4	81.5	19 3/4	80.3
		19/32									19 1/4	81.7	21 1/2	82.2
1 11/16	1 OR 1 1/8	17/32									21 1/4	82.9	18 3/4	79.8
		19/32									21 1/4	84.3	21	81.5
		21/32									24	84.3	23 1/2	83.2
1 3/4	1 OR 1 1/8	17/32									18 1/2	79.6	18	78.4
		19/32									21	81.6	20 1/4	80.6
		21/32									23 1/4	83.7	23	82.4

In driving rivets, wherever possible a machine should be used, of sufficient strength to fill the hole, and the rivet allowed to shrink and cool under pressure.

In the articles on boiler joints and boiler staying we have quoted freely from the Massachusetts Board of Boiler Rules and the recommendations of the American Society of Mechanical Engineers for a model engineer's and firemen's license law and boiler inspection law, these sources of information being unquestionably the most reliable upon this subject that are at present available.

Boiler Staying

IN the construction of boilers it is necessary, in order that all parts may have equal strength, to support flat surfaces or those likely to collapse, with stay rods or staybolts; the minimum thickness of all flat surface plates, which is recognized as safe, is 5/16 in., and this increases with pressure.

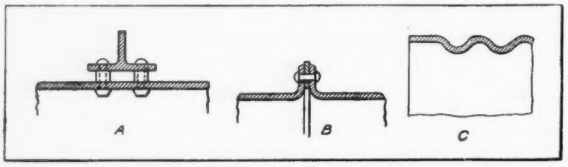


FIG. 1. METHOD OF STRENGTHENING FURNACES OF INTERNALLY FIRED BOILERS. A. STRENGTHENING RING. B. ADAMSON RING. C. CORRUGATED FLUE

On horizontal return tubular, locomotive, Scotch and similar boilers there is an area of the heads above and below the tubes subject to boiler pressure and which must be supported. Besides these surfaces there is a flat surface over the furnace in locomotive type boilers, also at the sides or water legs which must be stayed. In internally fired boilers where the external diameter of the furnace is 38 in. or less, except a corrugated furnace or one strengthened by an Adamson ring, or its equivalent, it is braced with one or more rows of stay bolts around the furnaces.

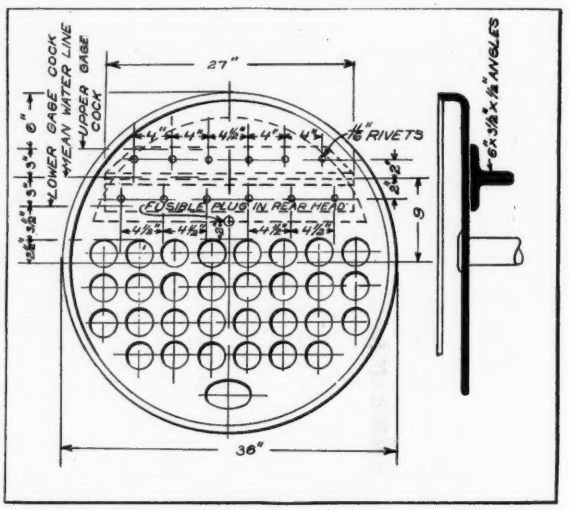


FIG. 2. BOILER HEAD BRACED WITH STEEL ANGLES

Where water legs are employed in water-tube boilers, these require support, but the drum heads, as ordinarily constructed, are convex, or bumped, and need no support.

Probably the simplest and most acceptable method of bracing the flat, unsupported surface of a horizontal return-tubular boiler less than 36 in. in diameter is by means of steel angles or tee bars when the pressure does not exceed 100 lb. per sq. in. The supporting angle is placed on the inside of the head and supports the surface as a beam uniformly loaded by being riveted to the head plate at uniform distances so as properly to support the plate from the edges near the shell, as shown by the accompanying sketch.

Where the diameter exceeds 36 in., it is customary to support the flat heads of horizontal return tubular, locomotive and Scotch boilers by through head to head, diagonal or crow foot stay rods. When these rods are not over 6 ft. long, they may be screwed through the

TABLE I. MAXIMUM ALLOWABLE PITCH OF SCREWED STAYBOLTS, ENDS RIVETED OVER

Pressure, in Pounds per Square Inch.	Thickness of Plate.						
	5/16"	3/8"	7/16"	1/2"	9/16"	5/8"	11/16"
	Maximum Pitch of Stay-bolts, in Inches.						
100,	5½	6¼	7	7⅝	8¼	–	–
110,	5⅛	6	6⅝	7⅜	8⅛	–	–
120,	5⅛	5⅝	6½	7⅛	7⅞	8½	–
125,	5	5⅝	6⅜	7	7¾	8⅜	–
130,	5	5⅝	6¼	6⅞	7⅝	8¼	–
140,	4⅞	5⅛	6	6⅝	7⅜	8	–
150,	4⅝	5⅛	5⅞	6½	7⅛	7⅝	8⅛
160,	4⅝	5⅛	5⅝	6¼	6⅞	7½	8
170,	4½	5	5⅝	6⅛	6⅝	7¼	7⅞
180,	4⅜	4⅞	5½	6	6½	7⅛	7⅝
190,	4⅜	4⅞	5⅜	5⅞	6⅜	7	7½
200,	4¼	4⅝	5¼	5¾	6¼	6¾	7⅜
225,	4⅛	4½	5	5½	6	6½	7
250,	4	4⅜	4¾	5⅛	5¾	6¼	6¾
300,	3¾	4⅛	4½	4⅞	5⅜	5¾	6⅛

F Strength of plate between rivet holes in second row, plus the crushing strength of the butt strap in front of 1 rivet in the outer row = (P − 2d) t × T. S. + d × b × c.

C Shearing strength of 16 rivets in double shear plus shear-strength of butt strap in front of 2 rivets in the second row and 1 rivet in the outer row = (P − 4d) t × T. S. + n × d × b × c.

H Crushing strength of plate in front of 8 rivets, plus crushing strength of butt strap in front of 3 rivets = N × d × t × c + n × d × b × c.

I Crushing strength of plate in front of 8 rivets, plus shearing strength of 2 rivets in the second row and one rivet in the outer row, in single shear = N × d × t × c + n × s × a.

For the quintuple rivet butt and double-strap joint the formulas are:

A Strength of solid plate = P × t × T. S.

B Strength of plate between rivet holes in outer row = (P − d) t × T. S.

C Shearing strength of 16 rivets in double shear plus shearing strength of 7 rivets in single shear = N × S × a + n × s × a.

D Strength of plate between rivet holes in the second row, plus the shearing strength of 1 rivet in single shear in the outer row = (P − 2d) t × T. S. + 1 × s × a.

E Strength of plate between rivet holes in third row, plus the shearing strength of 2 rivets in the second row in single shear with 1 rivet in single shear in the outer row = (P − 4d) t × T. S. + 3 × s × a.

F Strength of plate between rivet holes in the fourth row plus the shearing strength of 4 rivets in the third row, 2 rivets in the second row, and 1 rivet in the outer row in single shear = (P − 8d) t × T. S. + n × s × a.

G Strength of plate between rivet holes in second row, plus the crushing strength of butt strap in front of 1 rivet in the outer row = (P − 2d) t × T. S. + d × b × c.

H Strength of plate between rivet holes in the third row, plus crushing strength of butt strap in front of 2 rivets in the second row and 1 rivet in the outer row = (P − 4d) t × T. S. + 3 × d × b × c.

I Strength of plate between rivet holes in fourth row, plus the crushing strength of butt strap in front of 4 rivets in the third row, 2 rivets in the second row and 1 rivet in the outer row = (P − 8d) t × T. S. + n × d × b × c.

J Crushing strength of plate in front of 16 rivets, plus the crushing strength of butt strap in front of 7 rivets = N × d × t × c + n × d × b × c.

K Crushing strength of plate in front of 16 rivets, plus shearing strength of 4 rivets in the third row, 2 rivets in the second row and 1 rivet in the outer row in single shear = N × d × t × c + n × s × a.

sheet and riveted over, but when longer they are fastened with nuts to the heads, as illustrated. The tubes are beaded over at the ends to give additional support to the head. In some cases stay tubes are used when the end of the tube is made heavier and threaded and a nut screwed on the inside and outside of the plate, as shown by the sketch.

To attach stay rods to stayed surfaces a convenient arrangement is to rivet steel tees, angles or channels to the plate and bolt the stay rods to these; this arrangement provides for slight irregular expansion and contraction of the boiler shell, due to heat. Some of the

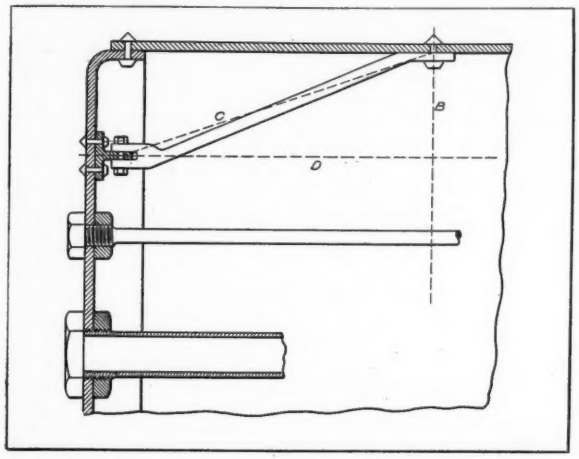


FIG. 3. METHODS OF FASTENING DIAGONAL AND THROUGH STAYS AND STAY TUBES TO BOILER HEADS

methods of using these fastenings are shown in the illustrations. Diagonal stay rods supporting the heads are usually attached to the shell by flattening one end and riveting it direct to the plate, while the other end is bolted to an angle or tee riveted to the head, as shown by the sketch.

TABLE II. MAXIMUM PITCH OF STAYBOLTS ON FURNACE SHEETS

MAXIMUM EXTERNAL DIA. OF FURNACE	THICKNESS OF FURNACE SHEET	MINIMUM DIA. OF STAY BOLTS OVER THREADS	PRESSURE IN POUNDS PER SQ. IN.							
			100	110	120	125	130	140	150	175
			MAXIMUM CIRCUMFERENTIAL PITCH							
—	1/4	—	4 3/4	4 5/8	4 1/2	4 3/8	4 3/8	4 1/4	4 1/8	3 7/8
—	5/16	—	5 1/8	5 1/4	5 1/8	5	5	4 3/4	4 3/4	4 1/2
			MAXIMUM LONGITUDINAL PITCH OF STAY BOLTS IN INCHES							
20	1/4	3/4	12 3/8	10 1/4	8 3/8	7 3/8	7 1/4	6 3/8	5 1/2	4
26	1/4	3/4	7 1/4	6	5 1/8	4 5/8	4 3/8	—	—	—
26	5/16	7/8	15 3/8	14 3/4	12 3/8	11 1/8	10 3/8	9	8	5 3/4
32	5/16	7/8	11 3/4	9 3/4	8 1/8	7 5/8	7	6	—	—
38	5/16	7/8	8 3/8	7	5 7/8	5 3/8	5	—	—	—

Staybolts supporting the flat plates of water legs are screwed through both plates and riveted over. These bolts may be threaded their entire length or only at the ends with the middle turned down to a diameter less than that of the root of the threads. In each end of the staybolt is a drilled hole, 3/16 in. in diameter and extending 1/2 in. or more within the inside of the plate; so as to show by a leak through the end of the stay bolt when a bolt has broken, as the break is most likely to occur near the plate and inspection in parts of boilers which must be stayed in this manner is not easy. In some water-tube boilers the staybolts are made hollow through the entire length, which besides the advantage mentioned above, provides openings into the gas passages through which steam or air may be blown to clean the water tubes of soot.

TABLE III. MAXIMUM ALLOWABLE STRESS ON STAYS

Material and Type.	Size up to and including 1¼" Diameter or Equivalent Area.	Size over 1¼" Diameter or Equivalent Area.
Weldless mild steel head to head or through stays,	8,000 lbs.	9,000 lbs.
Weldless mild steel diagonal or crow-foot stays,	7,500 lbs.	8,000 lbs.
Weldless wrought-iron head to head or through stays,	7,000 lbs.	7,500 lbs.
Weldless wrought-iron diagonal or crow-foot stays,	6,500 lbs.	7,000 lbs.
Welded mild steel or wrought-iron stays,	6,000 lbs.	6,000 lbs.
Mild steel or wrought-iron stay-bolts,	6,500 lbs.	7,000 lbs.

Above the tubes of a return tubular, locomotive, Scotch or similar boiler, is a segment of the flat head to be stayed. This area is inclosed by a line drawn 2 in. above the tubes and an arc 3 in. from the shell; it is considered that the small areas near the shell and the tubes are sufficiently well supported. The formula for calculating this area is:

$$\text{Area of segment} = \frac{4\,H^2}{3\sqrt{\frac{H}{2\,R}}} + 0.608$$

in which H is the distance from the top row of tubes to the shell minus 5, and R is the radius of the boiler minus 3; all dimensions are in inches.

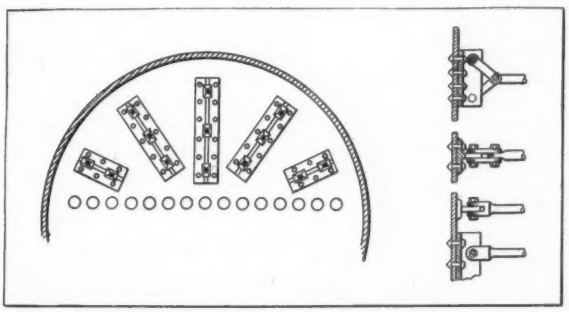


FIG. 4. USE OF STEEL TEES FOR ATTACHING STAYS TO BOILER HEADS

Beneath the tubes, the area to be stayed is calculated in the same manner, except that the lower row of tubes does not usually extend clear across the boiler, several tubes in the center being omitted, and the area they would take up must be added to that of the segment. In boilers 48 in. diameter and larger a manhole should be located below the tubes in the head, and in this case, if the flange is turned in around the opening to twice the thickness of the head, the area to be stayed will not include an area equal to a space 2 in. wide surrounding the manhole, as shown by the sketch, To find the area around an 11 by 15-in. manhole, for example, we have, area of an ellipse is the product of the diameters and 0.7854:

$15 \times 19 \times 0.7854 = 224$ sq. in. (nearly)
$11 \times 15 \times 0.7854 = 130$ sq. in. (nearly)
$224 - 130 = 94$ sq. in., which

is the area of the annular space not requiring staying.

Around furnaces in vertical boilers the surface to be stayed is measured from the center of the rivets at the

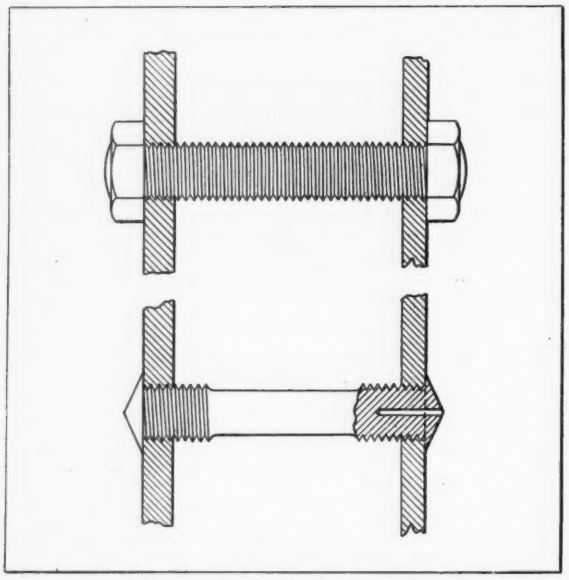


FIG. 5. FORMS OF STAYBOLTS

bottom of the waterleg to the center of the rivets in the bottom tube sheet and the pitch of the stay bolts is measured at the furnace sheet. When the longitudinal joint of the furnace sheet is of lap-riveted construction a

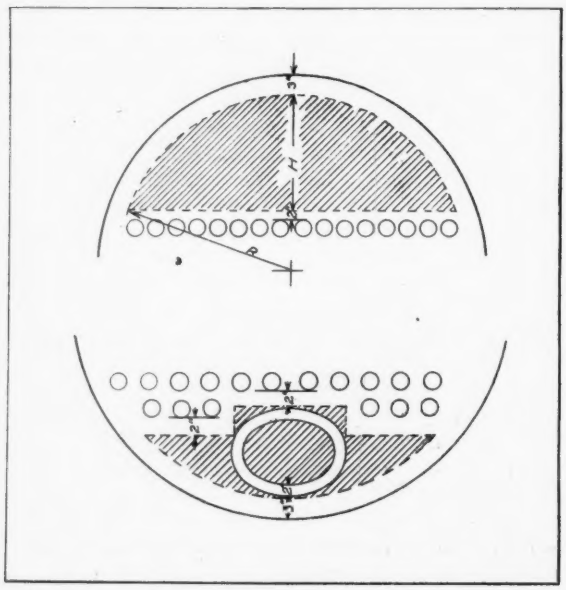


FIG. 6. SEGMENTS OF FLAT HEADS WHICH REQUIRE STAYING

staybolt in each row is placed near the joint, as shown by the sketch.

Allowable pitch of staybolts depends upon the thickness of the plate and the pressure to which the boiler is subjected. The maximum pitch, up to 8½ in., which should never be exceeded, may be found as follows:

Add 1 to the thickness of the plate in sixteenths of an inch, square this sum and multiply by 66, then divide by the working pressure in pounds per square inch, add 6 and extract the square root of the sum and the result will be the maximum allowable pitch in inches of screwed staybolts with ends riveted over.

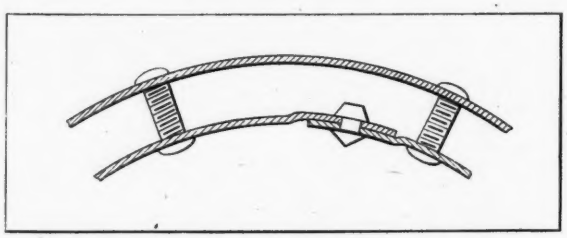


FIG. 7. SUPPORT FOR FURNACE SHEET NEAR RIVETED JOINT

The formula for this is:

$$S = \sqrt{\frac{66 \times (t+1)^2}{P}} + 6$$

S = maximum allowable pitch,
t = thickness of plate in sixteenths of an inch,
P = working pressure in pounds per square inch.

TABLE IV. MAXIMUM ALLOWABLE LOAD ON STAYBOLTS WITH 12 THREADS PER INCH

Outside Diameter of Stay-bolts, in Inches.	Diameter at Bottom of Thread, in Inches.	Net Cross-sectional Area (at Bottom of Thread), in Square Inches.	Allowable Load at 6,500 Pounds Stress, per Square Inch.	Allowable Load at 7,000 Pounds Stress, per Square Inch.
¾	.7500	.6057	.288	1,873	2,016
13/16	.8125	.6682	.351	2,282	2,457
⅞	.8750	.7307	.419	2,724	2,933
15/16	.9375	.7932	.494	3,211	3,458
1	1.0000	.8557	.575	3,738	4,025
1 1/16	1.0625	.9182	.662	4,303	4,634
1⅛	1.1250	.9807	.755	4,908	5,285
1 3/16	1.1875	1.0432	.855	5,558	5,985
1¼	1.2500	1.1057	.960	6,240	6,720
1 5/16	1.3125	1.1682	1.072	6,968	7,504
1⅜	1.3750	1.2307	1.190	7,735	8,330
1 7/16	1.4375	1.2932	1.313	8,535	9,191
1½	1.5000	1.3557	1.444	9,386	10,108

The accompanying Table II gives the maximum pitch as worked out by the above formula.

Having determined the pitch, the next step is to calculate the size of the staybolt. The strain placed upon one bolt is found by squaring the pitch in inches

TABLE V. MAXIMUM ALLOWABLE LOAD ON STAYBOLTS WITH 10 THREADS PER INCH

Outside Diameter of Stay-bolts, in Inches.	Diameter at Bottom of Thread, in Inches.	Net Cross-sectional Area (at Bottom of Thread), in Square Inches.	Allowable Load at 6,500 Pounds Stress, per Square Inch.	Allowable Load at 7,000 Pounds Stress, per Square Inch.
1¼	1.2500	1.0768	.911	5,921	6,377
1 5/16	1.3125	1.1393	1.019	6,623	7,133
1⅜	1.3750	1.2018	1.134	7,371	7,938
1 7/16	1.4375	1.2643	1.255	8,157	8,785
1½	1.5000	1.3268	1.382	8,983	9,674
1 9/16	1.5625	1.3893	1.515	9,847	10,605
1⅝	1.6250	1.4518	1.655	10,757	11,585

and multiplying by the working pressure. The maximum allowable stress per square inch of cross section on staybolts is as shown by the table.

To find the area of the staybolt, divide the strain upon bolt by the allowable stress per square inch found in Table III.

In the case of a horizontal return tubular boiler with a manhole below the tubes, one or more stays are bolted through the shell each side of the manhole and the rear

ends are attached to the rear head of the boiler. The center line of these stays must be in line or above the center line of the manhole.

TABLE VI. MAXIMUM ALLOWABLE LOAD ON CIRCULAR OR RECTANGULAR STAYS

Minimum Diameter of Circular Stay, in Inches.		Net Cross-sectional Area of Stay, in Square Inches.	Allowable Stress, in Pounds per Square Inch, Net Cross-sectional Area.					
			6,000	6,500	7,000	7,500	8,000	9,000
			Allowable Load, in Pounds, on Net Cross-sectional Area.					
1	1.0060	.7854	4,712	5,105	5,498	5,891	6,283	-
1 1/16	1.0625	.8896	5,320	5,763	6,206	6,650	7,093	-
1 1/8	1.1250	.9940	5,964	6,461	6,958	7,455	7,952	-
1 3/16	1.1875	1.1075	6,645	7,199	7,753	8,306	8,860	-
1 1/4	1.2500	1.2272	7,363	7,977	8,590	9,204	9,818	-
1 5/16	1.3125	1.3530	8,118	8,795	9,471	10,148	10,824	12,177
1 3/8	1.3750	1.4849	8,909	9,652	10,394	11,137	11,879	13,364
1 7/16	1.4375	1.6320	9,738	10,550	11,361	12,173	12,984	14,607
1 1/2	1.5000	1.7671	10,603	11,486	12,370	13,253	14,137	15,904
1 9/16	1.5625	1.9175	11,505	12,464	13,423	14,381	15,340	17,258
1 5/8	1.6250	2.0739	12,443	13,480	14,517	15,554	16,591	18,665
1 11/16	1.6875	2.2365	13,419	14,537	15,655	16,744	17,892	20,130
1 3/4	1.7500	2.4053	14,432	15,634	16,837	18,040	19,242	21,648
1 13/16	1.8125	2.5802	15,481	16,771	18,061	19,351	20,642	23,222
1 7/8	1.8750	2.7612	16,567	17,948	19,328	20,709	22,090	24,851
1 15/16	1.9375	2.9483	17,690	19,164	20,638	22,112	23,586	26,535
2	2.0000	3.1416	18,850	20,420	21,991	23,562	25,133	28,274
2 1/16	2.1250	3.5466	21,280	23,053	24,826	26,600	28,373	31,919
2 1/8	2.2500	3.9761	23,857	25,845	27,833	29,821	31,809	35,785
2 3/16	2.3750	4.4301	26,580	28,796	31,011	33,226	35,441	39,871
2 1/4	2.5000	4.9087	29,452	31,907	34,361	36,815	39,270	44,178
2 5/16	2.6250	5.4119	32,471	35,177	37,883	40,589	43,295	48,707
2 3/8	2.7500	5.9396	35,638	38,607	41,577	44,547	47,517	53,456
2 7/16	2.8750	6.4918	38,951	42,197	45,443	48,689	51,934	58,426
3	3.0000	7.0686	42,412	45,946	49,480	53,015	56,549	63,617

TABLE VII. MINIMUM NUMBER OF THREADS FOR PIPE CONNECTIONS TO BOILER

Size of pipe connection, in inches.	1 and 1¼	1½ and 2	2½ to 4 inclusive	4½ to 6 inclusive	7 and 8	9 and 10	12
Number of threads per inch.	11½	11½	8	8	8	8	8
Minimum number of threads required in opening.	4	5	7	8	10	12	18
Minimum thickness of material required to give above number of threads.	.348" (.375"=⅜")	.435" (.4375"=7/16")	.875"	1"	1.25"	1.5"	1.625"

When diagonal stays are used, the supporting power of the stay is reduced in the ratio of D to C, in the Fig. 3. In the case of threaded stays the minimum diameter, which is usually at the root of the threads, is that from which the strength of the stay is calculated.

Spacing of Tubes

AS an aid to proper circulation and easy cleaning, the tubes in tubular boilers are usually arranged in horizontal and vertical rows. In addition to this, some makers omit the middle vertical row of tubes and allow a space of not less than 3 in. between the outer tubes and the shell, a construction which is claimed to cause the cooler water to descend along the side of the shell, become heated, and then together with the steam generated, rise up the center.

To allow the tubes to be properly expanded and to prevent priming, they should be spaced not less than 1 in. vertically and 1⅛ in. horizontally between surfaces. The top row of tubes should be so placed as to be covered with plenty of water, at least 6 in. being desirable. The lower part of the shell is left devoid of any tubes. In boilers under 50 in. in diameter handholes are placed at the bottom of either one or both tube sheets, while in boilers over 50 in. in diameter a manhole is generally placed at the bottom of the front tube sheet, thus giving ready access to the bottom of the boiler for cleaning purposes. The table on page 7 gives the greatest number of tubes usually used in horizontal tubular boilers of various sizes.

Methods of Baffling

THE use of baffles is restricted to water-tube boilers and for each type of these a different system of baffling is usually necessary. Baffling is generally designated as being either horizontal or vertical, although its actual position may deviate more or less from either of these positions and still be called that toward which it more nearly inclines.

By referring to the illustrations of longitudinal sections of the horizontal water-tube boiler, page 24, a good idea of the position and location of common baffles may be obtained. These may, however, be changed to the so-called Sewall baffle as shown. In the vertical type baffling it is good practice to use about 42 per cent of the tube length for the width of the opening to the first pass, 33 per cent to the second and 25 per cent to the third or last pass; when using the horizontal baffle, an opening 30 per cent of tube length for the first pass and 33 per cent for the second are good practice.

Illustration of the horizontal baffling plainly shows the arrangement, in which, for good proportions, the first pass opening may be about 26 per cent of the tube length, while the opening in the second baffle can be about 20 per cent.

In the Stirling type of boiler, the baffle passages may well be 28, 20 and 15 per cent for the first, second and third passes, respectively.

The single pass horizontal baffle is often used in such boilers as the Atlas, Babcock & Wilcox, Erie City, Cahall horizontal, Edge Moor, Geary, Keeler and others of this general type of boiler. With this baffling, as shown in the longitudinal section of the Geary boiler, good results have been obtained when the first opening is 30 per cent of the tube length and the second 20 per cent thereof. In the cross-sectional view of the Wickes vertical water-tube boiler, Fig. 3, is shown the baffle extending vertically and dividing the gas passages into 2 parts or passes.

In addition to the regular baffling, most water-tube boilers have, over the furnace, a roof built up of sectional tiling extending from the front header to a trifle beyond the bridge wall. For the remaining distance, the ordinary tile baffling is used. With the tile roof, complete combustion with little or no excess of air has been produced, resulting in almost smokeless operation, and in addition to this, the boiler tubes are provided with protection from the hot furnace gases.

The position and location of baffling has a great bearing on the available draft in the various passes of a boiler and as a consequence affects the draft required. Many opinions exist among engineers as to the proper location of baffles and only a study of actual conditions in the particular boiler under consideration can give the best answer to this question. The Department of Smoke Inspection of the City of Chicago has carried on careful and thorough investigations along this line and by a study of Figs. 1, 2 and 3, a good idea may be gained of the effect on the available draft of different baffle settings in various types of boilers.

Draft Losses

IT has been said that the secret of efficient furnace and boiler operation lies in the proper handling of the air supply and the maintaining of proper draft losses through the setting. Just what these losses should be can be determined only after tests have been made under different conditions of load and systems of baffling. loss of draft through or around the tubes varies with the load carried. For example, with one type of water-tube boiler the draft loss through the setting at rated load is 0.2 in.; at 50 per cent overload the loss is increased to 0.4 in. This increase is due to the increased volume of gas that must pass around the tubes due to more fuel burned because of increased demand for heat. If the furnace is allowing too much air to pass through

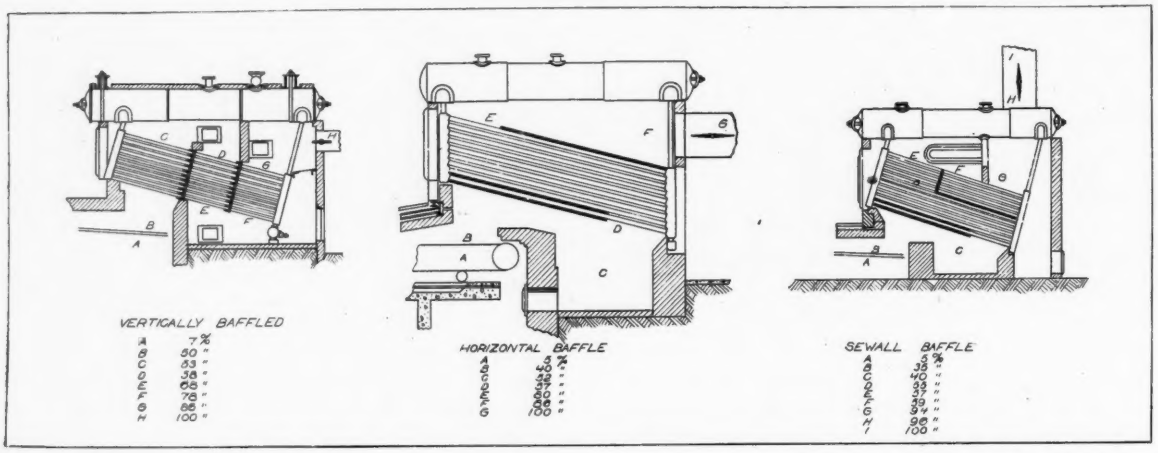


FIG. 1. AVAILABLE DRAFT IN VARIOUS SECTIONS OF THE SETTINGS OF HORIZONTAL WATER-TUBE BOILERS WITH DIFFERENT METHODS OF BAFFLING

The greatest loss of draft is through the bed of fuel, and this varies with the kind of fuel used, thickness of the bed carried and the rate of combustion. Coal that is coarse does not pack so tight as the finer grades and this allows more space for air to pass through; so run-of-mine bituminous coal does not cause so much loss in draft as does slack or anthracite coal.

the grates for the amount of coal being burned, the draft loss will be increased. Accumulation of soot on the tubes is another cause for increase in differential draft, while a fallen baffle is indicated by a decrease in draft loss.

When used alone, neither the furnace nor differential draft gage is of great value in the operation of the

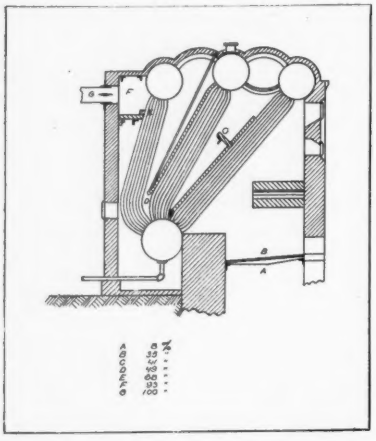


FIG. 2. AVAILABLE DRAFT IN VARIOUS PARTS OF A STIRLING WATER-TUBE BOILER SETTING

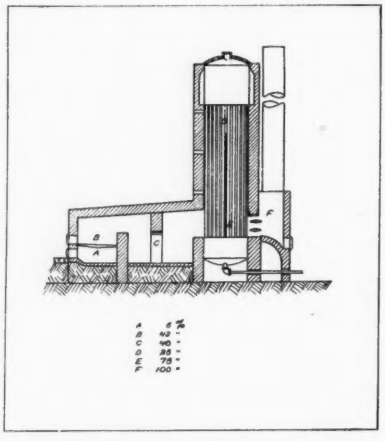


FIG. 3. DRAFT AVAILABLE IN VARIOUS PARTS OF A VERTICAL WATER-TUBE BOILER SETTING

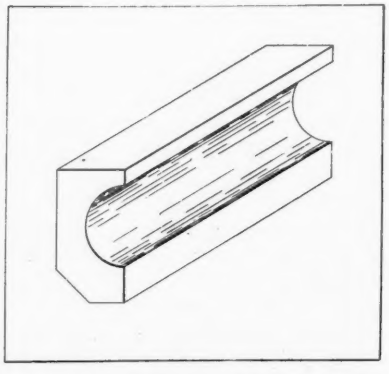


FIG. 4. FORM OF ROOF TILING PLACED OVER FURNACE OF HORIZONTAL WATER-TUBE BOILERS

Draft losses through the setting depend upon the type of boiler, system of baffling, condition of tubes, rate of combustion and consequently load carried on the boiler. Just what the loss through the setting should be must, as previously stated, be determined by tests for the individual installation. It may be said, however, that with proper combustion in the furnace the boiler, but when both are installed and proper tests have been made, they form a definite guide to the fireman. In a recent communication Ed. A. Uehling gives the following as what he considers the ideal draft gage equipment for boilers:

"The first thing to make sure of is the total motive force on which draft depends, i. e., the available pres-

sure differential between ashpit and chimney, where natural draft is relied on, or the ashpit and the suction side of the fan, where induced draft is employed. A recording draft gage should be installed to record this pressure differential, i. e., the total available draft. Where a number of boilers are served by one chimney, a draft gage (not necessarily recording) should be located at the farthest end of the smoke flue.

"This gage will show by difference, the resistance through the smoke flue, which, due to faulty construction, is often considerable. It also serves to discover air leakage into the smoke flue, the importance of which is not generally recognized. The reading of the flue draft gage should be taken at least twice a day and marked on the proper time line of the chart recording the chimney or fan draft.

"A positive and correct measure of the illegitimate burden imposed on the chimney due to air leakage is obtained by determining the per cent of CO_2 in the gases as they enter the chimney. The weight of the dry gases

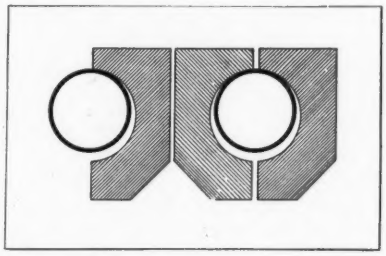


FIG. 5. SECTION OF ROOF TILING

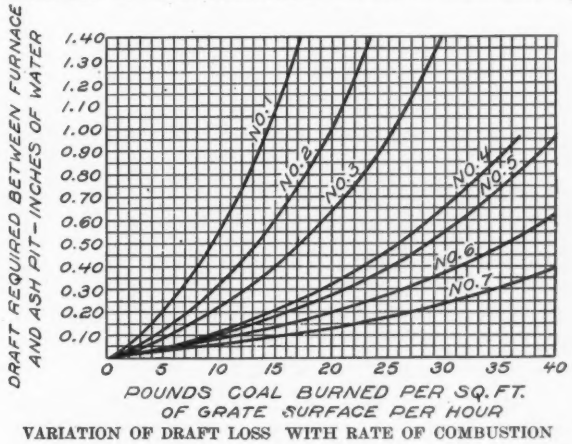
equals $1 + (243.6 \div P)$ per pound of carbon burned, in which P = per cent of CO_2. Substituting in this formula the value of P found in the chimney gases and then the average value of P from all the boilers as shown by the CO_2 recorders, or as determined from samples drawn from the gas exits of all the boilers simultaneously with the drawing of the sample from the chimney. The difference so found will represent the leakage per pound of carbon burned. For example, if the gases leave the boilers containing 12 per cent of CO_2, which would be a fairly good average, and the gases entering the chimney should contain only 8 per cent of CO_2, then we would have $[1 + (243.6 \div 8)] - [1 + (243.6 \div 12)]$ = 10.15 lb. of illegitimate burden imposed on the chimney for every pound of carbon burned, an increase of nearly 50 per cent over what it would be if the smoke flue and connections were perfectly tight.

"Where forced draft is employed a recording pressure gage should be located at the fan, and a pressure indicator at the extreme end of the air duct. This pressure indicator should be read at proper intervals and the readings transferred to the chart of the pressure recorder, thus recording the loss due to friction and leakage for the same purpose as indicated above in connection with smoke flue and chimney draft.

"Every boiler should be equipped with means for diagnosing the draft conditions. It is not sufficient for the firemen to know the total draft, i. e., the pressure differential between ashpit and damper. To operate intelligently he must be able to observe the variable resistance through the fire as well as the resistance to the flow of gases through the boiler. The latter is an index to the rate of driving and is therefore of special importance.

"A draft indicator or indicators that will put this information before the fireman is sufficient to enable him to regulate his fire intelligently. For an ideal draft equipment, every boiler should be supplied with a double draft recorder that will show in juxtaposition on the same chart, the total draft, the furnace draft and hence by difference, also the boiler draft."

The draft gage equipment proposed as most desirable for boilers by Fred K. Taylor, of the Hohmann & Maurer M'f'g Co., consists of: "One indicating gage for every boiler having pipe connection to the following points: the ashpit, over the grate, before the damper, and in the flue or breeching beyond the damper. Each one of these connections should be controlled by



VARIATION OF DRAFT LOSS WITH RATE OF COMBUSTION

the opening or closing of a stop cock close to the gage. The engineer then wishing to take the draft reading in the ashpit, for instance, would open up the cock on this line, leaving the others shut, and the gage would give him the reading. If he wishes to take the draft in the flue, he would close the ashpit cock and open the flue cock and the gage would also give this reading.

"If readings are taken on an indicating gage every hour, care being used to have constant draft conditions during the manipulation of the stop cocks, the difference in these readings would give a very good survey of boiler conditions and would immediately disclose leaks in the boiler wall, holes in the fire, etc. The difference between the reading in the ashpit and the reading above the grate would be especially valuable to determine thickness of the fuel in the grate, evenness of distribution of fuel, holes, etc., and would be a constant check on firing conditions."

The accompanying curve shows how the draft loss through the fuel varies with the rate of combustion and using the same grade of coal under similar load conditions, the draft will vary in nearly the same proportions as the thickness of fuel. Curve No. 1 is for anthracite buckwheat No. 3; curve No. 2, anthracite buckwheat No. 1; curve No. 3, anthracite pea coal; curve No. 4, bituminous slack on chain grate; curve No. 5, semi-bituminous run-of-mine; curve No. 6, bituminous slack; curve No. 7, bituminous run-of-mine.

Boiler Accessories

ONE OF THE MOST vital parts of a steam boiler is the water column. On this, which may vary in form and construction from the simple gage glass connected to the water and steam spaces to the elaborate patented apparatus with its settling chamber, signal apparatus and chain-pull, self-closing valves, the fireman depends to determine the level of the water in his boiler.

Water Columns

THE EXACT location of the water column varies not only in different types of boilers, but even in boilers of the same make, so only a general statement may be made relative to this. Opinions differ considerably in regard to the height at which the gage glass should be placed, some preferring to have the bottom of the glass at a level with the top row of tubes, while others prefer to place it higher so that when the water appears in the glass, there will be a safe depth of it over the tubes. This latter method would seem preferable and is by all means the safer.

From 3½ to 5 in. above the top row of tubes will be found a safe depth, the lesser value being used only when unusual confidence may be placed on the feeding apparatus. Whatever the location of the column may be, care should be taken that it is carefully connected and that the pipes are level and of the proper size, nothing less than 1-in. pipe being recommended where the length is greater than 6 or 8 in.

Valves or plug cocks should not be used in the column connections and where the connection is such as to necessitate a bend, it is better to use tees and crosses than ells. The unused ends of these may then be plugged so as to allow ready and easy cleaning or blowing out of the pipes and connections. Unions employing rubber gaskets should be avoided, as particles of the rubber lodging in any part of the column or its connections might cause serious trouble.

Care of Columns

AS THE try cocks and gage glass are the sole means by which the fireman can determine the level of the water in the boiler, more than ordinary care should be given these parts and it is advisable to blow the column out at least once a day and as much as 3 times a day if the condition of the water warrants it. After blowing out, the try cocks should be opened to see that the height of the water indicated by them corresponds to that in the glass, and the accuracy of the glass should be tried at least twice a day with good water and oftener if the water is bad.

High and Low Alarms

AS A further aid to the attendant, many water columns are provided with high and low water alarms. These ordinarily consist of copper floats placed in the column and, by means of a system of levers, controlling a steam whistle which is blown whenever the position of the float is above or below the upper or lower try cock. The principle of operation of these alarms is shown in the accompanying cuts.

Feed Water Regulators

A HABIT with some firemen is to fill their boilers to the third gage and then shut off the source of supply until the water has gone down nearly to the bottom of the glass, when they will again feed the boiler. This not only necessitates additional labor for the attendant, but causes the boiler to have a varying load. While the boiler is carrying its regular load, it is being filled with a great amount of comparatively cold water which it will have to heat to the temperature of the contained water, calling not only for extra work on the part of the fireman but also for an additional consumption of fuel.

To feed a boiler properly, replace the water as it is being evaporated. With a steady load on the boiler, this can be easily done by running the feed pump at a speed to replace the water that is being evaporated. With a varying load such as is found in most plants, it is difficult to maintain a constant water level without the use of some automatic regulator.

Under normal operating conditions, it is found that a good feed water regulator can and will maintain a level within from ¼ to 1 in. of the desired mark. Some regulators are designed so as not to maintain a constant level but to lower the water level at heavy loads and raise it at light loads, the variation in height being adjusted according to local conditions. By this method little or no water is fed to the boiler during the coming on of heavy load, thus allowing all the available heat to be utilized in the generation of steam, but during the change to no-load or light load periods, the feeding is accelerated and the available heat is used to bring the temperature of the incoming excess water up to that of the contained water.

While the use of a feed water regulator does result in a more uniform consumption of fuel, there is considerable difference of opinion as to the actual saving resulting aside from the reduction of labor.

The Burrows Regulator

THIS regulator with high and low water alarm, as shown herewith, consists of a water column somewhat larger in diameter than usually used. Placed therein is a copper float, which rises and falls with the level of the water and which, upon rising, actuates the lever J to allow the passage of steam through the whistle, thus sounding the high level alarm, draws up lever A below the float, and by means of link B closes the valve located below the column, shutting off the supply of feed water. After the supply valve is closed, the level of the water in the boiler gradually drops and with it the float. As the float moves downward, the valve is again opened a trifle, allowing the flow of water into the boiler.

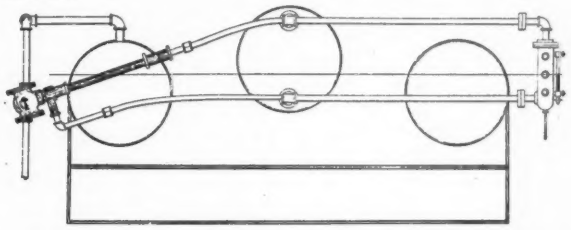
In the operation of this regulator, the general tendency is to have the feed valve open just enough to supply the proper amount of water required and it can be readily seen that unless trouble arises, the high and low alarms are never put to use, as it is claimed by the makers of this regulator, the Burrows Manufacturing

Co., of York, Pa., that the water line in a horizontal return tubular boiler can be kept within ½ in. from a fixed point and in a water-tube boiler within 1 in.

Elliott Feed Water Regulator

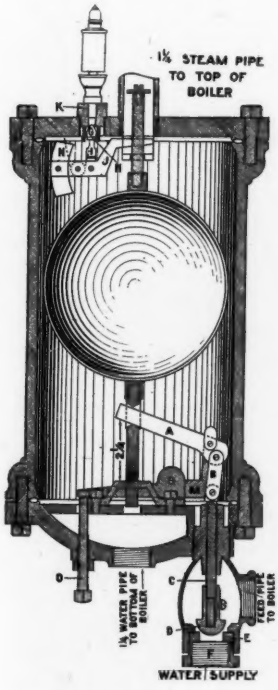
The Elliott feed water regulator here shown consists of the regulation water column, 1, containing a float, 2, with stem extending through the guide plate and engaging lever 4, which actuates the pilot valve 10. To this valve is connected the exhaust line 7 and line 8 leading to the feed water regulating valve.

When the water in the boiler is at its normal level, the valve on the end of stem 5 is open, while the valve on the end of stem 9 is closed, allowing the steam to pass through pipe 8 and exert its pressure against the regulating valve diaphragm, thus cutting off the feed water supply. As the water in the boiler evaporates, the water level in the boiler and the column lowers, and the weight of the float is gradually transferred to lever 4, overcoming the steam pressure and unseating valve 9. The weight of the float then closes the admission valve, and the steam contained in pipe 8 passes through the exhaust valve, and by way of pipe 7 into the atmosphere, relieving the pressure on top of the diaphragm and permitting the regulating valve to open and admit water to the boiler. This continues until the water level has been raised about 2 in., and as it rises in the boiler and the column, the float has a tendency to rise likewise; but the steam pressure on the admission valve tends to keep it closed, consequently prevents the float from rising until the weight due to the increased displacement of the float overcomes the pressure at the admission valve, and as it opens, the exhaust valve 9 closes, causing the steam to enter the regulating-valve pipe 8, forcing the controlling valve to its seat, thus shutting off the feed supply.

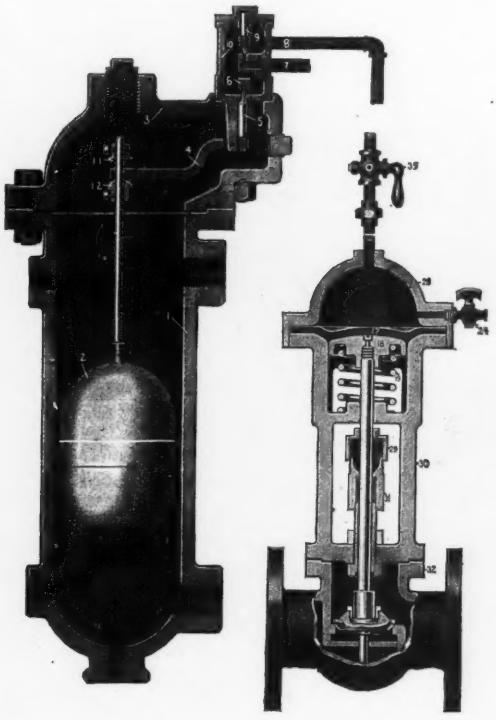


MC DONOUGH REGULATOR APPLIED TO STIRLING BOILER

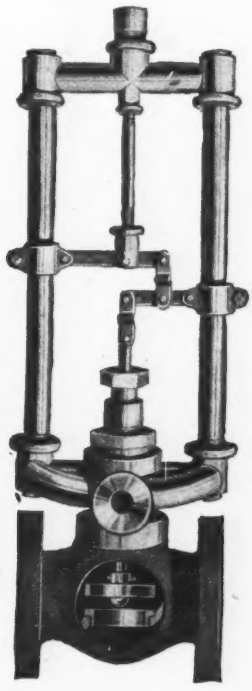
The Elliott Co., of Pittsburgh, Pa., are the manufacturers of this regulator.



INTERNAL CONSTRUCTION OF BURROWS FEED WATER REGULATOR



ELLIOTT FEED WATER REGULATOR



MC DONOUGH REGULATOR

McDonough Automatic Regulator

The McDonough feed water regulator depends for its operation upon the expansion and contraction of 2 thermostatic tubes which open and close the feed valve through a system of levers. The regulator is connected to the steam and water spaces of the boiler, and as the water falls or rises in the boiler, it falls or rises in the expansion tubes, causing them to expand or contract, thus regulating the flow of water to the boiler, which may be adjusted so as to meet the demand. By means of the levers shown, the valve disk is moved in a ratio

of 5 to 1 over the amount of expansion or contraction of the tubes and it is claimed that the slightest change in the temperature of the tubes has an immediate effect in changing the position of the valve disk.

Adjustment is obtained by means of a turnbuckle, while the position of the valve is indicated by an indicator on the side.

This regulator is manufactured by the McDonough Automatic Regulator Co., of Detroit, Mich.

Murray Feed Water Regulator

In this regulator, the water column is arranged as shown so that the rise and fall of a float controls the small valve A which, upon the fall of the water level, admits steam through the small pipe into the lower end of cylinder B, forcing up the piston P against the tension of the spring and by means of the piston rod C opens the regulating valve V. This action admits water through the feed pipe into the boiler until the normal level is restored, when the needle valve will again close by the rising of the float, shutting off the steam from the ¼-in. pipe and allowing the spring to close the piston, thus closing the regulating valve.

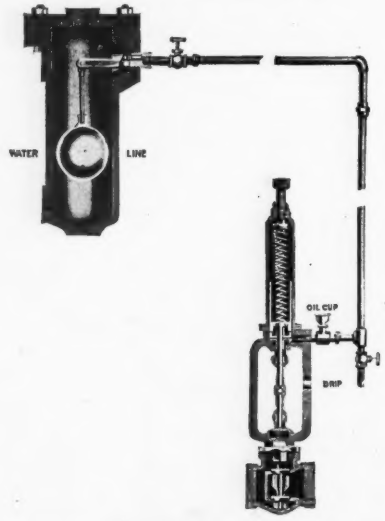


DIAGRAM OF CONNECTIONS OF THE MURRAY REGULATOR

The Murray regulator is made by the Murray Manufacturing Co., of Detroit, Mich.

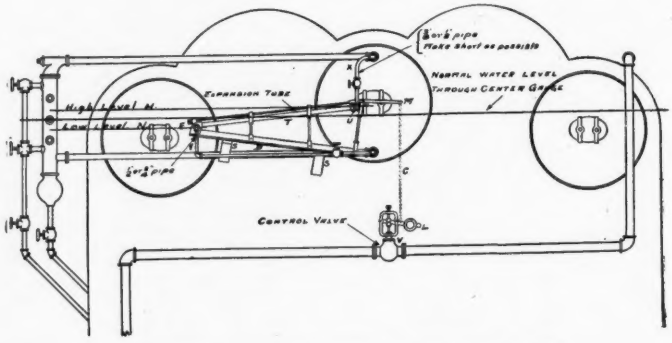
Copes Feed Water Regulators

This regulator, made by the Northern Equipment Co., of Erie, Pa., depends for its operation upon the expansion and contraction of an inclined tube, operating through a system of levers, a valve which controls the flow of water to the boiler. As illustrated, this inclined tube is so placed, in the submerged type, that when the water in the boiler is at its lowest level, the tube contains steam, and as the water gradually rises in the boiler, it rises in the tube also. When the level of the water is as shown, part of the tube is filled with steam and is at the temperature of the steam, while that part of the tube containing water is at a lower temperature.

When an increased load comes on, there is a slight drop in steam pressure, accompanied by a more rapid liberation of steam from the entire body of water within the boiler, causing a corresponding increase in its volume and a rise in the boiler water level. This at once raises the level of the water in the expansion tube slightly, increases the amount of the tube submerged in the water and decreases the tube temperature, causing it to shorten. As this tube is connected by a simple system of levers to a balanced valve in the feed line, shortening of the tube causes the valve to close, so that increase in the boiler load by causing the rise in water level, results in a decrease in the rate of feed. This is the action desired in this type of regulator to obtain the maximum capacity of the boiler, since the heat being generated in the furnace is used to generate steam, and not to heat the feed water at a time when the steam is needed.

As the heavy load continues, the evaporation of water causes the level to drop with a consequent expansion of the tube and gradual opening of the feed valve until a point is reached where the rate of feed equals the rate of evaporation and equilibrium is restored, the water being at a new level.

Suppose as before that the boiler load is about normal and the water level is at the height No. 2. A decrease in load means a smaller steam demand, and a rise in boiler pressure, causing the fireman to decrease his draft, which results in a smaller generation of steam and a slight dropping of the water level with an accompanying heating up and expansion of the tube. This immediately causes the feed valve to open wider and feed the water at a higher rate, thus absorbing and storing heat which the furnace would otherwise waste. The rising water cools the expansion tube and slowly cuts down the feed again so that at any fixed load position the rate of feed becomes just equal to the rate of evaporation.



COPES SUBMERGED FEED WATER REGULATOR

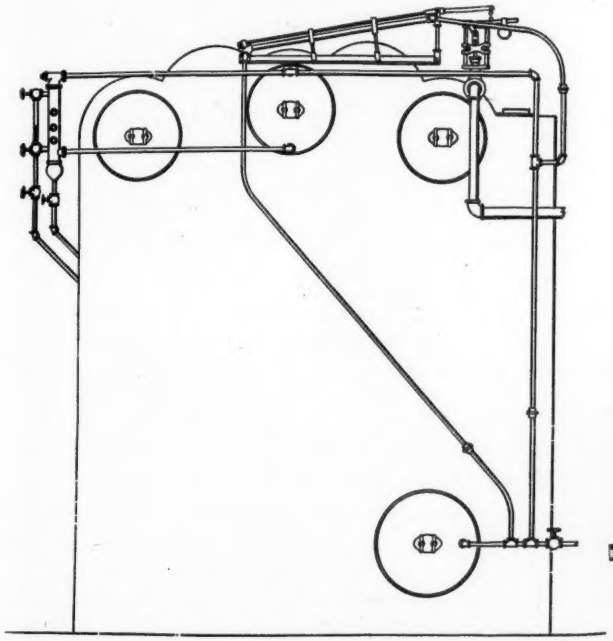
For boilers carrying a practically uniform load or one whose peaks rise gradually, this company builds a regulator which in general appearance is similar to the submerged type, but which is placed above the water line with its upper connection brought down to the desired water level. When this level drops, steam is admitted to the tube, causing it to expand, opening the feed valve and thus allowing the water to rise until it cuts off the steam supply to the tube. The contained steam then condenses, the tube cools and contracts and gradually closes the valve.

The "S-C" Feed Water Regulator

As shown in the accompanying illustration, this regulator consists of a generator surrounded by a radiator, connected to the water column and so placed that the mean water level in the generator will correspond to the mean water level in the boiler. At the bottom of the generator is attached a flexible tube leading to the feed control valve.

The tube connecting the generator to the lower water column outlet is under boiler pressure and contains water up to the corresponding water level in the boiler, the portion above being filled with steam while the generator and flexible tubing up to the diaphragm of the control valve contain water. Water in the tube connecting the generator to the boiler is exposed to radiation through the fittings and is at a temperature below the boiling point, while the upper part of this tube, being filled with steam, is at a considerably higher temperature and as a result the hot part will have a tendency to boil the water in generator, creating a pressure which through the flexible tubing acts on the diaphragm of the control valve, causing this to open and admit water to the boiler. The rising water in the boiler and consequently in the connecting tube also, together with the effect brought about by the radiator surrounding generator, cools the water in the generator, reduces the pressure and as a result allows the control valve to close.

The "S-C" Regulator Co., of Fostoria, O., makes this regulator.



COPES FEED WATER REGULATOR AS APPLIED TO STIRLING BOILER

THE "S-C" REGULATOR

The Squires Automatic Feed Water Controller

As seen by the accompanying illustration, this controller or regulator consists of a system of heavy copper tubes arranged as shown and called the harp. The extreme ends of these copper tubes are connected by means of a rod, turn buckle and an auxiliary valve B, having a steam inlet from the harp and 2 outlets, one to regulating valve A and the other an exhaust.

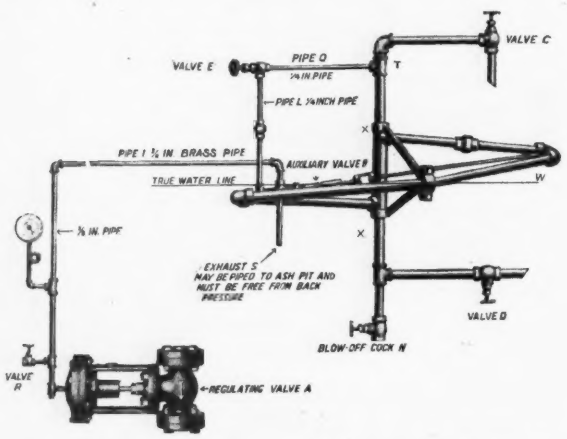
The harp is held by and connected to a heavy cast-iron column so placed on the boiler that the true water line is as indicated. Consider valve A closed and the water at its true level. As the boiler gives off steam, the water line drops and the harp becomes filled with more steam, causing it to expand, pulling against the spring in auxiliary valve B, causes the pressure in the diaphragm of valve A to be released, and allow more water into the boiler. This causing the water to rise and consequently filling the copper tube, results in the contraction of the harp, which in turn allows the spring in auxiliary valve B to close the port between the regulating valve and the exhaust. Steam now entering the auxiliary valve from the harp passes the resistance plug valve and gradually builds up a pressure against the diaphragm of the regulating valve, closing it and shutting off the water.

The C. E. Squires Co. of Cleveland, O., manufactures this regulator.

The Strong Method of Feed Water Regulation

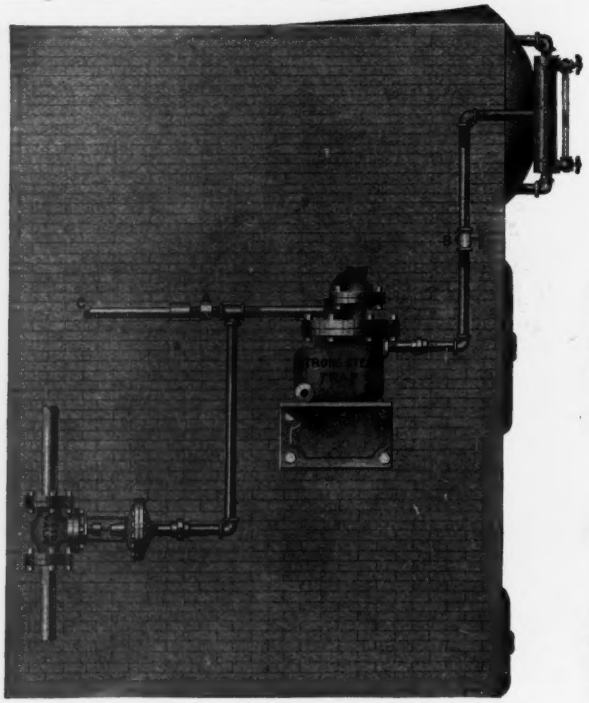
One of the simplest methods of boiler feed regulation is that employed by the Strong, Carlisle & Hammond Co., of Cleveland, Ohio. In this system, use is made of a steam trap which constitutes the controlling mechanism. The inlet of the trap is connected to the water column or boiler drum at the water line, while the outlet is connected to a tee, the opposite side of which con-

nects to the pipe C through the fitting A, which consists of a small orifice acting as a bleeder, while the side of the tee connects to the feed control valve as shown.



SQUIRES FEED WATER REGULATOR SHOWING DIAGRAM OF CONNECTIONS

Water rising in the boiler overflows into the trap and causes the trap valve to open, admitting boiler pressure to the diaphragm chamber of the feed valve, thus closing the feed line. As soon as the water in the boiler falls below the intake to the trap, the trap valve closes, the pressure on the feed valve exhausts through fitting A and the feed valve opens.



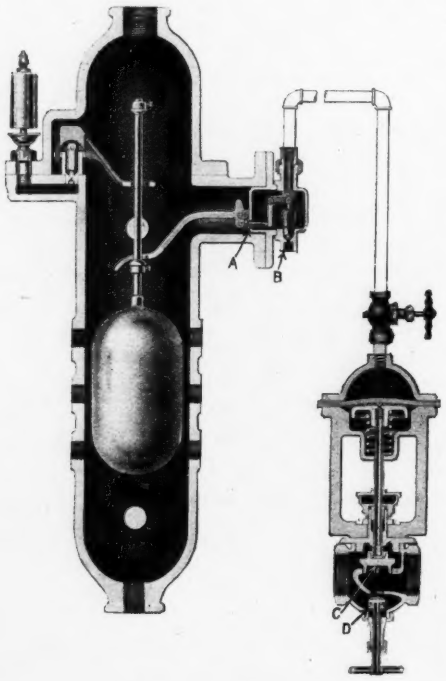
STRONG METHOD OF FEED WATER REGULATION

The regulator is controlled by valve B, the opening of which places it in operation, while closing this valve cuts the regulator out of service and opens the feed valve.

The Williams Feed Water Regulator

This regulator consists of a water column with float, levers and control valves connected to the feed-water regulating valve, as shown in the illustration.

Assume the water in the column to be at its normal level and the feed regulating valve closed. As the water in the boiler evaporates, the float in the water column falls and in doing so closes the steam inlet valve and opens the exhaust valve, relieving the pressure from the regulating valve diaphragm, and allowing the water to pass into the boiler.



WILLIAMS FEED WATER REGULATOR

After the water and also the float rise above the normal level, the exhaust valve is closed and the steam valve opened, allowing the steam pressure to act on the regulating valve diaphragm, thus closing this valve and cutting off the supply of water to the boiler.

This regulator is made by the Williams Gauge Co., Pittsburgh, Pa.

Gage Cocks

TRY cocks or gage cocks set at points above and below the water level, are as a general rule connected to the water column, although they have in the past been connected directly to the boiler shell. An advantage claimed for the latter method is that, if by accident or by stoppage of the pipe connections the water column should become inoperative, it would still be possible to determine the approximate water level by use of the cocks, which are set within the length of the glass.

As ordinarily constructed, try cocks consist of needle valves to the stems of which are attached small weights used to keep the cocks closed. With the ordinary gage

cock, it is necessary for the fireman to climb up to the water column every time he desires to try them and to eliminate this trouble various patented devices have been placed upon the market where usually, by means of chains, the fireman is able to trip the cocks from the floor level, a method similar to that sometimes used for the control of the water glass valves.

Water columns should be blown out once a day and the gage cocks opened to see that the height of the water indicated corresponds with that shown by the glass.

Fusible Plugs

FUSIBLE or safety plugs are ordinarily constructed of brass or bronze in the forms shown in the illustration, and are made hollow with a tapering opening having the small end next to the fire. They are divided into 2 general types, the inside plug and the outside plug, and as their names imply, are screwed into the boiler sheet from the inside, or from the outside respectively, and shaped as shown in the Fusible Plug Specifications, the latter being in most cases preferable.

For both types of plugs the outside of the body has cut upon it a standard pipe thread so that it may be screwed into the shell sheet. One end is provided with a hexagonal shoulder to fit a wrench easily and when in place the body of the plug extends a trifle above the inside of the sheet, to prevent the formation of scale on the face of the plug.

Alloys Used

Alloys of bismuth have been used for making fusible plugs, but it has been found that the melting points of these alloys are altered by the continued action of heat, so that they cannot be relied upon to melt at the proper temperature. Plugs made of pure Banca tin may, however, be relied upon to melt at or very near the desired temperature.

Location

Massachusetts Boiler Rules state that each boiler shall have one or more fusible plugs located as follows:

Projection through the sheet is specified in practically all types of boilers as "not less than 1 in." For horizontal return tube or flue boilers, location in the rear head, the center of the plug, not less than 2 in. above the upper surface of the upper row of tubes; and in flue, on a line with the highest part of the boiler exposed to products of combustion. In locomotive type or star water-tube, location in the highest part of the crown sheet.

In vertical fire tube boilers, with dry upper sheet, not less than ⅓ the length of tube above the lower sheet, and except in the Corliss type, in an outside tube. For the submerged tube type, in the upper tube sheet.

For water-tube boilers, horizontal type, in the upper drum, not less than 6 in. above the bottom of the drum, for vertical baffling above the first pass of the products of combustion, and for inclined drums, in the highest course of the drum.

In Stirling boilers, for the standard type, in the front side of middle drum not less than 4 in. above the bottom; for superheater type, in the front drum not less than 6 in. above the bottom.

In Robb-Mumford boilers, location in the bottom of the steam and water drum, 24 in. from the center of the rear neck. In Almy type water-tube, in a tube or fitting exposed to the products of combustion.

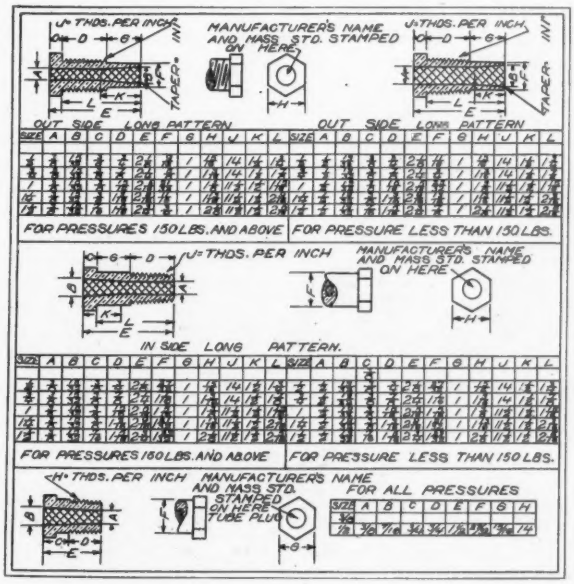
In vertical boilers such as Climax or Hazleton, in a tube or center drum, not less than ½ the height of the shell measuring from the lowest circumferential seam.

In Cahall vertical water-tube boilers, in the inner sheet of the top drum, not less than 6 in. above the upper tube sheet.

For Scotch boilers; marine type, in combustion chamber top; in dry back type, in rear head, not less than 2 in. above the upper row of tubes.

For cast-iron sectional heating boilers, in a section over and in direct contact with the products of combustion in the primary combustion chamber.

FUSIBLE PLUG SPECIFICATIONS


U= THDS. PER INCH
MANUFACTURER'S NAME AND MASS STD. STAMPED ON HERE
TAPER
OUT SIDE LONG PATTERN
FOR PRESSURES 150 LBS. AND ABOVE
FOR PRESSURE LESS THAN 150 LBS.
IN SIDE LONG PATTERN.
H= THDS. PER INCH
MANUFACTURERS NAME AND MASS STD. STAMPED ON HERE TUBE PLUG
FOR ALL PRESSURES

For water-tube boilers, Worthington type, in the front side of the steam and water drum, not less than 4 in. above the bottom of the drum.

For other types and new designs, placed at the lowest permissible water level, in the direct path of the products of combustion, as near the primary combustion chamber as possible.

Specifications

Table herewith gives specifications recently adopted by the Massachusetts Board of Boiler Rules.

In addition, it is specified that all fusible plugs used in the State of Massachusetts shall consist of bronze casings, the holes of which shall be reamed and tinned and filled with Banca tin. The outside diameter of the plug is to be of some standard pipe size, and it is further stated that no fusible plug shall be used for a period of more than 1 yr.

Feed Line Discharge

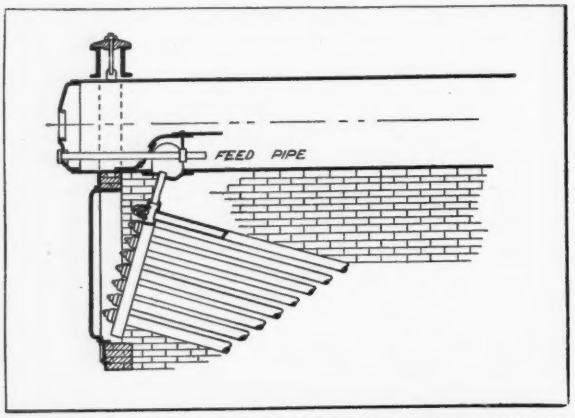
CORRECT feeding of a steam boiler calls for the introduction of water at a temperature as near as possible that of the contained water, since the boiler must heat the water to the temperature of the steam corresponding to the working pressure before it can generate the steam required.

While the exact location of the discharge varies in each type of boiler, the direction of the discharge should be such as to promote the natural circulation of the water in the boiler rather than hinder it, and away from riveted joints in shell or furnace sheets.

In the vertical water-tube boiler, such as the Wickes, the feed water enters in the rear of the upper drum, descends through the rear tubes, which act as a heater, passes through the bottom drum and rises through the front tubes, again entering the upper drum.

In the Stirling boiler, a feed water discharge pan is provided, located just below the water line so that the water pouring out of it passes down the rear bank of tubes, where it becomes heated to a temperature almost equal to that of the contained water. In this type of boiler, the rear bank of tubes acts largely to heat feed water.

Many horizontal water-tube boilers use a mud drum located at the bottom of the upper shell, into which not only the feed water discharges, but a good part of the scale-forming matter is precipitated. The accompanying illustration shows the method employed in feeding horizontal water-tube boilers by passing the feed line through the front drum head and through a special water baffle so that the discharge takes place directly above and a little to the rear of the front header opening.



METHOD OF PASSING FEED LINE THROUGH FRONT HEAD OF DRUM AND DISCHARGING BEYOND HEADER

Where no heating or circulating device is used, feed water should be discharged in a return tubular boiler, 3/5 the length from the front head, near and above the central rows of tubes, the pipe entering through a bushing or reinforcement in the head or the shell near the front end, and being scarcely fastened inside the shell above the tubes.

In the feed line to each boiler should be placed a check valve and a stop valve, the stop valve being between the boiler and the check valve so that repairs may be made to the check valve while the boiler is under pressure. A globe valve must be set with the inlet under the disk. It is well to provide 2 methods of feeding the boiler and 2 feed inlet pipes, although, frequently, it is not done. Where a turn is made in the feed pipe, it is better to use a tee than an elbow, so that, by removing the plug from the unused end of the tee, inspection of the pipe may be made and cleaning done when necessary.

The feed line should be carried in front of the boiler and the control valve placed within easy reach of the attendant while standing on the floor.

DIMENSIONS OF HORIZONTAL TUBULAR BOILERS

Size		Stack	Stack	Grate	Safety	Feed	Blowoff	Steam	Heating
Diam. In.	Len. Ft.	Diam. In.	Ht. Ft.	Area Sq.Ft.	Valve Diam. In.	Pipe Diam. In.	Diam. In.	Nozzle Diam. In.	Surface Sq. Ft.
30	8	14	24	7.35	1.5	1	1	-	147
32	8	14	24	8.08	1.5	1	1	1.5	150
32	10	14	28	8.08	1.5	1	1	1.5	167
36	8	16	28	8.08	2	1	1.25	2	191
36	10	16	28	8.08	2	1	1.25	2	220
36	12	16	30	8.08	2	2	1.25	2.5	210
36	14	16	30	9.04	2	2	1.25	2.5	245
36	16	16	30	12.05	2	1	1.25	2.5	380
40	10	18	34	10.55	2.5	1	1.25	2.5	321
40	12	18	34	10.55	2.5	1	1.25	2.5	365
40	14	18	34	12.05	2.5	1	1.25	2.5	356
40	16	18	34	16.10	2.5	1	1.25	2.5	514
42	12	20	36	12.40	2.5	1	1.25	2.5	314
42	14	20	36	14.10	2.5	1	1.25	2.5	471
42	16	20	36	16.10	2.5	1	1.25	2.5	537
44	12	20	36	13.50	3	1.25	1.5	2.5	442
44	14	20	36	14.10	3	1.25	1.5	2.5	518
44	16	20	40	15.85	3	1.25	1.5	2.5	591
44	18	20	40	16.55	3	1.25	1.5	2.5	664
48	12	24	36	14.10	3	1.5	1.5	2.5	520
48	14	24	36	14.80	3	1.5	1.5	3	607
48	16	24	40	16.55	3	1.5	1.5	3	693
48	18	24	40	17.35	3	1.5	1.5	3	781
54	12	26	42	16.10	3.5	1.5	1.5	3.5	637
54	14	26	42	18.08	3.5	1.5	1.5	3.5	813
54	16	26	48	20.30	3.5	1.5	1.5	3.5	861
54	18	26	48	20.30	3.5	1.5	1.5	3.5	957
60	12	28	48	18.08	4	1.5	2	3.5	764
60	14	28	48	20.30	4	1.5	2	3.5	881
60	16	28	60	22.50	4	1.5	2	3.5	1008
60	18	28	60	22.50	4	1.5	2	4	1134
60	20	28	60	25	4	1.5	2	4	1265
66	14	32	50	22.50	5	2	2	4	1201
66	16	32	60	22.50	5	2	2	4	1376
66	18	32	60	25	5	2	2	4.5	1546
66	20	32	60	25	5	2	2	4.5	1719
72	14	36	50	24.70	5	2	2	4.5	1404
72	16	36	60	27.50	5	2	2	4.5	1603
72	18	36	60	30.25	5	2	2	4.5	1800
72	20	36	60	33	6	2	2	4.5	1996

Blowoffs

FOR the proper removal of scum, precipitated scale-forming materials and mud, every boiler is provided with one or more blowoffs. The blowoff used for disposing of the material from near the surface of the water consists of some form of funnel, made and placed so that it will operate regardless of the water level. To give this type of blowoff a wider range of operation, it is sometimes provided with a float so that the opening of the funnel will at all times be in register with the surface of the water.

Another type of blowoff is used in connection with the mud drum, into which the feed line discharges and where large amounts of scale-forming material precipitate, requiring frequent removal.

The blowoff found on all boilers is the one connected to the lowest point of the boiler and by means of which not only may sludge, mud, etc., be removed, but the boiler may be drained of its entire contents of water. This blowoff should be connected to a dead-water space.

Surface blowoffs should not be over 1½-in. pipe and carried through the shell or head with a bushing. For the bottom blowoff, the minimum size should be 1 in. and the maximum 2½ in. and for pressures over 15 lb. should be extra heavy from boiler to valve, without bushings or reducers. Globe valves are not to be used and above 125 lb. 2 valves or a valve and a cock must be provided, though these are always advisable.

In piping up the blowoffs, the usual practice is to connect the several boilers to a common line which carries all sediment and water to some proper place of disposal. This may be a nearby stream or lake, or it may become necessary to blow into a public sewerage system. But in such case, it is not only advisable but usually required by local ordinances to connect to a blowoff tank, the sediment and water being blown into the tank and permitted to cool before delivery to the sewer.

This tank may be a shell as shown in the cut with inlet, overflow and vent to the roof, or it may be a pit of brick or concrete. For tanks, the sheet is usually ¼ in. thick and joints single riveted. The capacity may well be 1/24 the volume of the boilers, neglecting the tubes, that are to be blown down at one time. Usually unless there are more than 3 boilers, it will be best to consider that all are to be blown down at once, and allow the tank accordingly.

Blowoff lines which are in the path of hot flue gases are usually covered with magnesia, asbestos or fire brick and, in the case of forced draft installations, additional measures are taken to prevent the burning away of the pipe, such as encasing in a larger pipe. In this case, it is desirable to connect the blowoff as shown in the cut on page 8, so that while it is not being used, a continuous circulation of water is maintained through it, thus keeping the pipe comparatively cool.

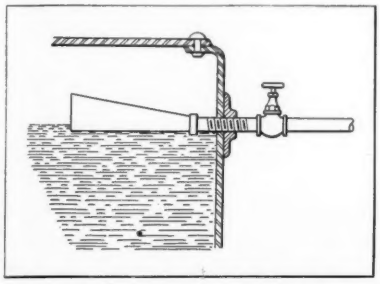


FIG. 1. SURFACE BLOWOFF

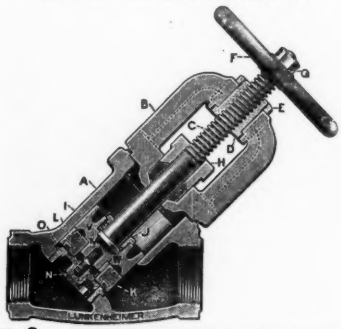


FIG. 2. LUNKENHEIMER BLOWOFF VALVE

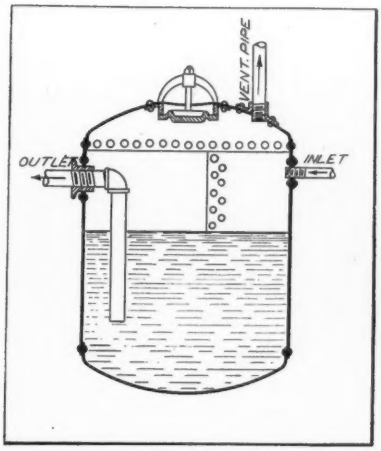


FIG. 1A. BLOWOFF TANK

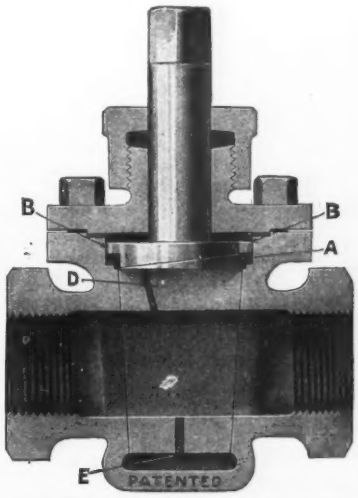


FIG. 7. SECTIONAL VIEW OF HOMESTEAD STRAIGHTWAY VALVE

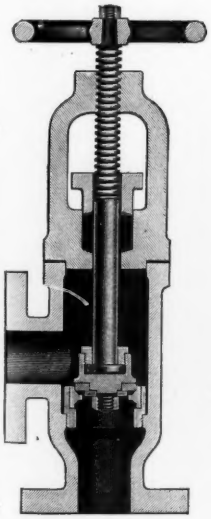


FIG. 3. PRATT & CADY BLOWOFF VALVE

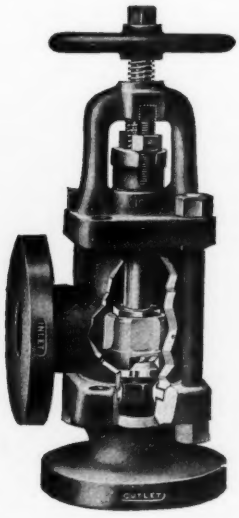


FIG. 4. THE CADMAN INDESTRUCTIBLE BLOWOFF VALVE

FIG. 5. INTERNAL CONSTRUCTION OF EVERLASTING BLOWOFF VALVE
FIG. 6. THE BASHLIN BLOWOFF VALVE

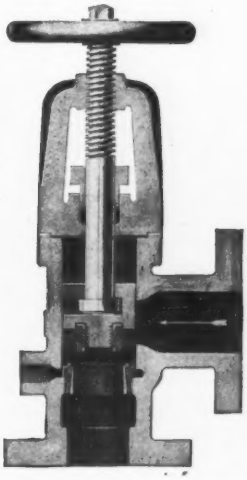


FIG. 8. FABER BLOWOFF VALVE

Blowoff Cocks and Valves

The requirements of a good blowoff valve are that it shall furnish a free passage for scale and sediment, that it shall close tight so as not to leak and that it shall open easily without cutting or sticking. On account of the rather severe service to which these valves are put, they are usually made extra heavy, with renewable wearing parts and should be made of material capable of withstanding the action of acids and alkalis and the severe action of superheated steam.

It is advisable to design the blowoff branch leading from the boiler to the header so that the severe strains due to extreme expansion and contraction do not affect them. Short and rigid connections should be avoided and all possible flexibility given to the branch and header.

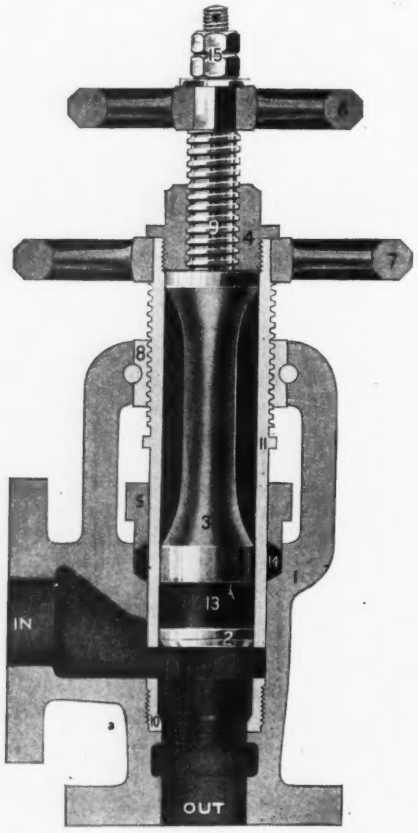


FIG. 9. EYNON-EVANS EXTRA HEAVY BLOWOFF VALVE

Blowoff valves are made in various styles and types, having, as a rule, straight through flow but with plug cock, disk or shutter style of closure. Some types are described following.

Typical Blowoff Valves

Figure 2 illustrates a straightway or Y blowoff, for working pressures up to 175 lb., with iron-body, brass-mounted and provided with renewable seats and renewable and reversible disks, both sides of the disks having a seating face made of a lead alloy which may readily be melted out and replaced with new material.

The blowoff valve shown in Fig. 3 has both renewable and reversible seat and disk, made of special metal, the seat being at an angle of 45 deg. to prevent lodgement of scale or dirt and being depressed below the inlet opening to protect it from impact of the water when blowing off. This valve has a brass stem and deep and large stuffing box, the bolts of which are hinged, making repacking easy.

In Fig. 4 is shown a valve with reversible seat and disk, the former being of phosphor bronze. Rugged construction makes it impossible for water to leak between the valve body and base and it is claimed that expansion and contraction have no effect.

Figure 5 shows a sliding disk blowoff valve composed of a top and bottom bonnet, a disk and a lever and post, which is largely used in stationary service and is claimed to be self-grinding and self-compensating at all points.

Figure 6 shows a Y blowoff valve with renewable disk and seat, the latter of which may be replaced through the plug opening shown. The disk is renewed by removing the bonnet, but since it is the seat which is more often damaged, the annoyance of changing disks is greatly reduced.

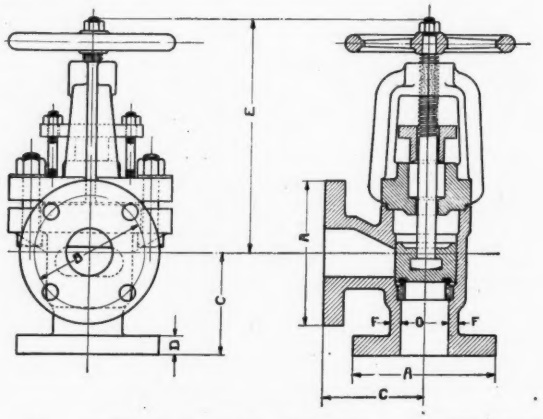


FIG. 10. PITTSBURGH VALVE, FOUNDRY & CONSTRUCTION CO.'S STANDARD BLOWOFF VALVE

The straightway valve, of Fig. 7, is so constructed that when closed the plug is forced to its seat, by means of the traveling cam A through which the stem passes, and which is prevented from turning by means of lugs B moving vertically in slots. E, D are balancing ports allowing the pressure to act at the top of the plug, gently holding it in its seat while the valve is open. The advantages claimed for this valve are: quick opening, straight passage, ease of operation and safety.

The flanged Faber blowoff valve shown in Fig. 8 is provided with means for cleansing the disk and seat by a jet of steam or water after the fluid is practically shut off, but before the valve is finally closed.

When the disk is in the position shown, the water is practically shut off and any sediment lying on the seat at this instant would remain there were no means provided for its removal. Surrounding the seat is a chamber into which steam is introduced at boiler pressure through a ½-in. connection leading from the steam main and shown at the left of the cut. The outside diameter of the seat is 1/16 in. smaller than the bore of the

valve. A 1/32-in. opening all around the seat is thus formed through which the steam escapes from the chamber surrounding the seat and impinges on the disk and seat thoroughly cleansing them from sediment.

A double blowoff valve consisting of the main valve 11 and auxiliary valve, each controlled by separate hand wheels 13, is shown in Fig. 9. This blowoff valve is so designed that when the boiler is being blown down, the anti-leak valve, 11, is protected from the cutting and wearing action of the material being discharged. When worn out, piston 11 may be replaced or repacked while the boiler is under pressure.

In order to open this valve, small wheel 6 is rotated until piston 3 strikes stop 4, after which the large wheel 7 is turned to the left to any desired opening of the main valve 11. To close, the large wheel is turned until valve 2 comes in contact with seat 10, when the small wheel is turned until the piston 11 comes in contact with seat 10.

The blowoff valve shown in Fig. 10 has a bronze seat and a renewable disk with a ring of babbit. The babbit, being the softer of the 2 metals, will take the cutting, leaving the brass ring of the body in good condition.

Safety Valves

THREE types of safety valves in use at the present time are the dead weight, the lever and the pop.

The dead weight valve, the simplest form of safety valve, is held on its seat against the boiler pressure by a cast-iron weight and has the advantage not only of great simplicity but of being least affected by tampering, since it requires so much weight that any additional amount which would seriously overload it can be quickly detected. For large, high-pressure boilers, this class of valve is entirely too cumbersome.

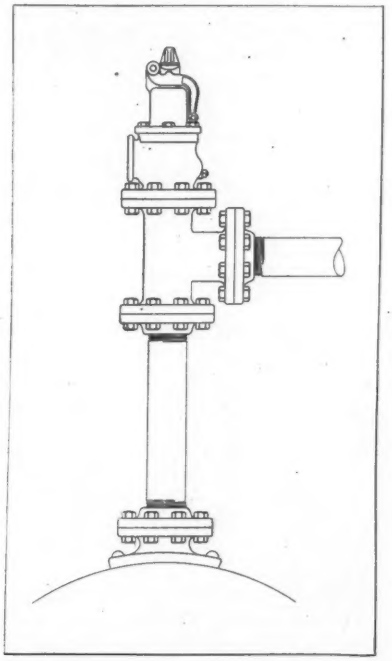
TABLE I. SIZE OF SAFETY VALVES, NOT SPRING LOADED, RELATIVE TO STEAM PRESSURE AND GRATE AREA

Maximum Pressure allowed per Sq.In. on Boiler		Zero to 25 Lb.	Over 25 to 50 Lb.	Over 50 to 100 Lb.
Diameter of Valve, In.	Area of Valve, Sq. In.	Area of Grate, Sq.Ft.		
1	0.7854	1.50	1.75	2.00
1¼	1.2272	2.25	2.50	3.00
1½	1.7671	3.00	3.75	4.00
2	3.1416	5.50	6.50	7.25
2½	4.9087	8.25	10.00	11.00
3	7.0686	11.75	14.25	16.00
3½	9.6211	16.00	19.50	21.75
4	12.5660	21.00	25.50	28.25
4½	15.9040	26.75	32.50	36.00
5	19.6350	32.75	40.00	44.00

In the lever type, the valve is held against its seat by a weight and lever permitting the use of a much smaller weight than the former type. To determine the pressure at which a lever safety valve will blow, multiply the weight of the lever by the distance of its center of gravity from the pivot; multiply the weight of the ball by its distance from the pivot; multiply the weight of the valve disk and stem by their distance from the pivot, and divide the sum of these 3 products by the product obtained by multiplying the area of the valve by the distance of the valve stem from the pivot; the quotient is the pressure at which the valve will lift.

To determine the size of a lever safety valve, it is usual to allow 1 sq. in. of valve area for every 2 sq. ft. of grate area. This is but an approximate value, the exact amount of valve area allowed per square foot of grate area for various pressures may more readily be determined from the accompanying table, proposed by a committee of the American Society of Mechanical Engineers.

The lift of any safety valve should be such that the area of the opening is equal to or slightly greater than the area of the valve disk. If the angle of the seat is 45 deg., the area of the opening in square inches equals the circumference of the disk times the lift times 0.707, the cosine of 45 deg. Knowing the area of the valve disk in square inches, we can readily transpose and find that the lift required is equal to the area of the valve opening in square inches divided by the circumference of the disk times 0.707.



IMPROPER METHOD OF CONNECTING SAFETY VALVE TO BOILER

In the pop safety valve, the disk is held against the seat by a strong helical spring so adjusted that the valve will open at a predetermined value of the steam pressure. In this valve, a ring surrounds the valve disk, preventing it from discharging until the valve has lifted somewhat. As soon as the valve begins to discharge, there is an additional rise due to the force of the steam rushing up against the bottom of the valve and holding it open until the pressure has dropped somewhat below that at which the valve began to discharge. This difference in pressure is termed the pop or blowback.

Instead of basing the size of pop safety valves upon the amount of heating surface or grate surface of a boiler, a committee of the American Society of Mechanical Engineers recommends using the steaming capacity

of the boiler, and has prepared the accompanying table of Discharge Capacities for Direct Spring Loaded Pop Safety Valves, in which the discharge capacity of each valve size at the given pressure is calculated upon the values of lifts unanimously approved by safety valve manufacturers. C is the total weight in pounds of fuel burned per hour at time of maximum forcing and H is the heat of combustion in British thermal units per pound of fuel used. In preparing this table, a boiler efficiency of 75 per cent and a valve discharge efficiency of 96 per cent were assumed.

Illustrations

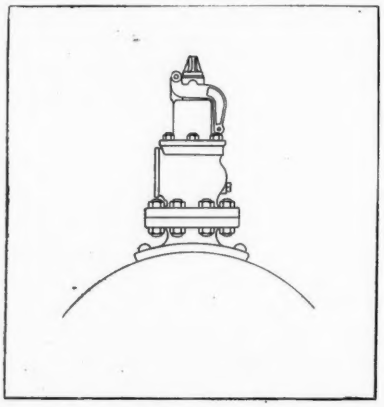
A BOILER at time of maximum forcing uses 2150 lb. of Illinois coal containing 12,100 B.t.u. per lb. Boiler pressure is 225 lb. gage.

CH or 2150 × 12,100 = 26,015,000. Referring to the table of the discharge capacities of spring loaded pop safety valves, we find under gage pressure of 225 lb., no single valve large enough to care for this capacity. Under the 4-in. valve, we find, however, CH = 13,264,000. We can, therefore, use 2 4-in. valves having 45-deg. seats or 1 3½-in. and 1 4½-in. valve with 45-deg. seats.

An oil-fired boiler at maximum forcing uses 1000 lb. of crude oil per hour, having a heat value of 18,500 B.t.u. per lb.; boiler pressure, 275 gage.

In this case, CH = 1000 × 18,500 = 18,500,000. Under a gage pressure of 275 lb., we find that it will be necessary to use 1 3-in. and 1 3½-in. bevel seat valves or 1 3-in. and 1 2½-in. valves with flat seats.

must be of a diameter equal to, or greater than the diameter of the valve disk and must be properly drained to avoid the collection of water. If the discharge pipe is of considerable weight, it should be properly supported to relieve the valve body of any strain and when placed



PROPER METHOD OF CONNECTING SAFETY VALVE TO BOILER

in a vertical position, a large radius bend with bleeder attached to the lowest point to remove all condensation, should be used instead of an ell.

The proposed boiler code of the American Society of Mechanical Engineers states that each boiler carrying more than 15 lb. gage pressure shall have 2 or more

TABLE II. DISCHARGE CAPACITIES FOR DIRECT SPRING LOADED POP SAFETY VALVES

Gage Pressure, Lb.		1 In.	1½ In.	2 In.	2½ In.	3 In.	3½ In.	4 In.	4½ In.
15	Lift, in.	0.057	0.070	0.083	0.096	0.109	0.122	0.135	0.147
	CH 45 deg. seat	272,300	501,600	793,000	1,147,000	1,562,000	2,040,000	2,580,000	3,158,000
	CH flat seat	385,100	709,400	1,122,000	1,622,000	2,209,000	2,885,000	3,648,000	4,466,000
25	Lift, in.	0.056	0.069	0.082	0.095	0.107	0.120	0.132	0.144
	CH 45 deg. seat	357,100	657,800	1,047,000	1,513,000	2,050,000	2,682,000	3,384,000	4,138,000
	CH flat seat	505,000	930,200	1,481,000	2,140,000	2,899,000	3,793,000	4,786,000	5,852,000
50	Lift, in.	0.053	0.065	0.078	0.090	0.102	0.114	0.127	0.138
	CH 45 deg. seat	551,500	1,020,000	1,624,000	2,342,000	3,185,000	4,153,000	5,287,000	6,463,000
	CH flat seat	780,000	1,442,000	2,296,000	3,312,000	4,504,000	5,873,000	7,477,000	9,140,000
75	Lift, in.	0.050	0.062	0.074	0.086	0.097	0.109	0.121	0.132
	CH 45 deg. seat	721,200	1,342,000	2,135,000	3,102,000	4,198,000	5,498,000	6,983,000	8,570,000
	CH flat seat	1,020,000	1,898,000	3,020,000	4,387,000	5,938,000	7,775,000	9,876,000	12,120,000
100	Lift, in.	0.047	0.058	0.069	0.081	0.093	0.104	0.115	0.126
	CH 45 deg. seat	866,900	1,605,000	2,546,000	3,727,000	5,093,000	6,698,000	8,487,000	10,462,000
	CH flat seat	1,226,000	2,270,000	3,601,000	5,271,000	7,202,000	9,472,000	12,003,000	14,795,000
125	Lift, in.	0.044	0.055	0.066	0.077	0.087	0.098	0.109	0.120
	CH 45 deg. seat	988,500	1,843,000	2,966,000	4,315,000	5,865,000	7,707,000	9,798,000	12,135,000
	CH flat seat	1,398,000	2,606,000	4,196,000	6,102,000	8,295,000	10,900,000	13,856,000	17,161,000
150	Lift, in.	0.041	0.051	0.062	0.072	0.082	0.093	0.104	0.114
	CH 45 deg. seat	1,086,000	2,013,000	3,285,000	4,769,000	6,517,000	8,610,000	11,021,000	13,591,000
	CH flat seat	1,536,000	2,847,000	4,646,000	6,744,000	9,217,000	12,177,000	15,586,000	19,221,000
175	Lift, in.	0.038	0.048	0.058	0.068	0.078	0.088	0.098	0.107
	CH 45 deg. seat	1,159,000	2,197,000	3,540,000	5,187,000	7,140,000	9,399,000	11,961,000	14,677,000
	CH flat seat	1,640,000	3,107,000	5,006,000	7,336,000	10,098,000	13,292,000	16,916,000	20,757,000
200	Lift, in.	0.035	0.044	0.054	0.063	0.072	0.082	0.092	0.101
	CH 45 deg. seat	1,208,000	2,280,000	3,730,000	5,422,000	7,460,000	9,912,000	12,710,000	15,679,000
	CH flat seat	1,709,000	3,224,000	5,275,000	7,668,000	10,550,000	14,017,000	17,974,000	22,174,000
225	Lift, in.	0.031	0.040	0.049	0.059	0.068	0.077	0.086	0.095
	CH 45 deg. seat	1,095,000	2,314,000	3,779,000	5,668,000	7,866,000	10,372,000	13,264,000	16,351,000
	CH flat seat	1,690,000	3,272,000	5,344,000	8,016,000	11,124,000	14,688,000	18,758,000	23,124,000
250	Lift, in.	0.028	0.037	0.046	0.054	0.063	0.072	0.080	0.088
	CH 45 deg. seat	1,192,000	2,342,000	3,917,000	5,748,000	8,048,000	10,730,000	13,625,000	16,861,000
	CH flat seat	1,686,000	3,312,000	5,540,000	8,129,000	11,381,000	15,174,000	19,269,000	23,845,000
275	Lift, in.	0.025	0.033	0.042	0.050	0.058	0.066	0.074	0.082
	CH 45 deg. seat	1,165,000	2,283,000	3,915,000	5,825,000	8,108,000	10,765,000	13,794,000	17,195,000
	CH flat seat	1,648,000	3,229,000	5,536,000	8,238,000	11,467,000	15,224,000	19,507,000	24,318,000
300	Lift, in.	0.022	0.030	0.037	0.045	0.053	0.061	0.069	0.078
	CH 45 deg. seat	1,114,000	2,278,000	3,746,000	5,670,000	8,049,000	10,783,000	13,972,000	17,313,000
	CH flat seat	1,575,000	3,222,000	5,298,000	8,018,000	11,383,000	15,249,000	19,759,000	24,484,000

Location and Piping

ALL SAFETY valves should be located at the highest possible point on the boiler. If the escape of steam becomes a nuisance, the outlet of the safety valve may be piped to the atmosphere, in which case, the pipe so used

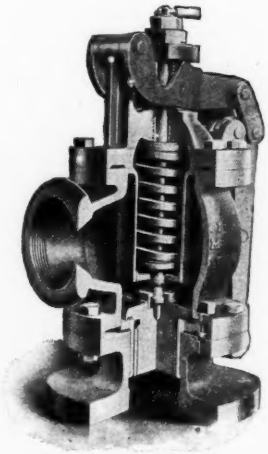
safety valves; that the discharge of safety valves shall be in accordance with the values given in the accompanying table; that the several safety valves on a boiler shall be set not to open at the same pressure; that the safety valve must be connected directly to the boiler,

independent of any other steam connection, and not upon a pipe; and that the valves shall be regulated to have ample blowdown.

The code further states that safety valves shall be set and adjusted for a 2-lb. blowdown on boilers carrying a pressure of 15 lb. gage or less; for a 3-lb. blowdown on boilers carrying a pressure more than 15 lb. gage and up to and including 125 lb. gage; for a 4-lb. blowdown on boilers operating under pressures of from 126 to 200 lb. gage and for a blowdown of 6 lb. on boilers carrying over 200 lb. gage pressure.

Types of Safety Valves

The American Special pop safety valve, made either of cast iron, gun metal or cast steel, is fitted with an American blowdown ring, and an encased spring, the compression of which governs the valve opening point and which may be adjusted by a compression screw, threaded in the valve bonnet and seated in the follower on top of the spring. The blowback is controlled by an adjustable ring giving an opening in the lip of the valve proper through the huddling chamber and is set at the desired points by grooved screws set diametrically oppo-



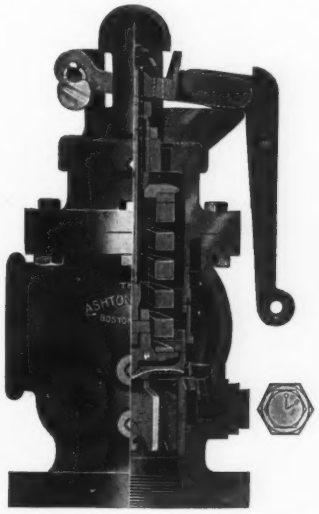
AMERICAN POP SAFETY VALVE

site each other and extending outside of the casing. While the valve proper, beveled at an angle of 45 deg., is made of bronze, the seat may be of bronze, nickel or any other metal specified. The valve bushing or body seat is made solid and expanded into the valve casing at the lower end, preventing the seat from rising under pressure. By means of compound lifting levers and link, the movement of lift is in a vertical direction throughout the required range, little effort being required to lift the valve.

Ashton Improved Lock-Up pop safety valve for large, high-pressure boilers, is made with 45-deg. beveled seats of nickel or a composition metal, lock-up attachment and adjustable cam lever. A distinctive feature is the pop chamber with knife-edge lip, which wears down in proportion to the wear of the valve seat, keeping the outlet of the pop chamber of the same relative proportion to the inlet, giving an unvarying pop and eliminating any special adjusting device to prevent increased pop and the unnecessary loss of steam. Iron body and locomotive valves have supplemental chamber to provide close regulation of the pop.

Springs used in this valve are of Jessop's steel, ground square on the ends and provided with pivoted disks in order to give them a true bearing on the valve.

In form A, Consolidated safety valves, casings and covers are of iron, with bushings and mountings of special bronze composition, while the seats in all cases are of nickel, a metal absolutely non-corrodible and capable



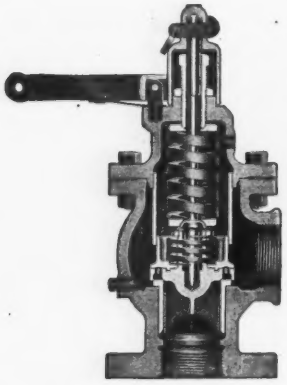
ASHTON IMPROVED LOCK-UP POP SAFETY VALVE

of withstanding severe oxidizing action. Form B stationary safety valve has a steel casing and all other mountings of nickel. Central thrust of the spindle upon the valve disk and freedom of the spring from a tendency to cramp or bind the spindle is obtained by mounting the spring to the end of the compression screw above and to the spindle below. A special feature of this valve is the ball seat, ground down by a spherical balling tool, a construction responsible for the exceptional tightness of these valves. Blowdown of a Consolidated safety valve is controlled by a Richardson adjusting ring. To change the blowdown, the hexagonal head lock screw in the side of the base casting is removed and a pointed tool inserted until it enters the slotted edge of the ring. Turning the ring down will decrease the blowdown, while turning it up will increase the blowdown.

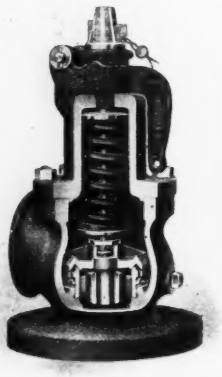
Crane iron body pop safety valves for working pressures up to 250 lb. gage are provided with nickel or brass valve seats beveled at an angle of 45 deg. To permit moderate changes in the setting pressures and maintain small waste of steam from blowback, this valve is provided with a self-adjusting auxiliary valve and spring. The steam in the pop chamber finds a passage through holes or ports into an annular space provided in the auxiliary valve or disk and due to a light auxiliary spring, this pressure lifts the auxiliary valve, allowing the steam in the pop chamber to escape gradually, supplying a cushion or balancing medium and affording the easiest possible action in the closing of the main valve without chattering or hammering. For changing the set pressure within reasonable limits, turn down or up, for a higher or lower pressure respectively, on the screw pressure plug at the top of the valve.

This valve is supplied, if desired, with a lock-up arrangement, also with a chamber enclosing the springs so as to protect them from the action of the high-pressure steam.

The Crosby safety valve, which is of the heavy type for use with saturated or superheated steam at high working pressures, has seat inclined at 45 deg. to the vertical so that when the valve opens, the passage between the seat and disk face is in a diagonally downward direction. Regulation of the blowback is effected by deflecting part of the escaping steam downward inside the valve lip through vent holes drilled in the bottom of the chamber surrounding the valve seat, the necessary adjustments being made possible by means of a regulating ring or gate threaded upon the base of the seat below the lip chamber. This regulating discharge is additional to the main discharge over the edge of the valve lip and produces a high discharge efficiency. This



CRANE POP SAFETY VALVE



CROSBY SAFETY VALVE

valve has a mushroom shaped disk with guide stem about ¼ the valve diameter moving in a guide suspended below the level of the valve seat by arms cast radially from the sides of the valve inlet. This smaller diameter guide is claimed to permit a free movement with little tendency to stick, and that the wear is uniform. The Crosby valve has an encased spring and a locked hinged cap covering the top of the valve, enclosing the lifting device, preventing tampering.

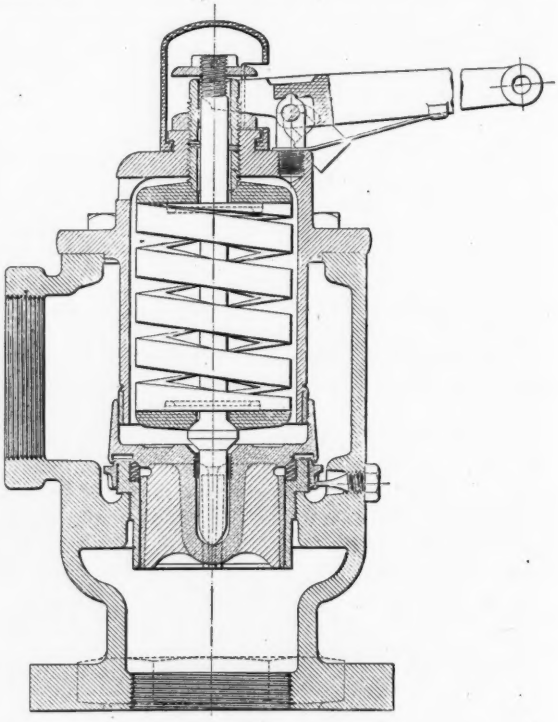
Steam Baffles

BAFFLES, constructed of boiler sheet, are so placed in the shells of some boilers as to meet and deflect the rising circulating water so as not only to guide it along its proper course, but also to prevent the rapidly moving water from spraying, and entering the steam outlet and passing over to the engines.

The baffling shown in the cut of the Wickes vertical water-tube boiler well illustrates its use in that type of steam generator. This baffling is placed in the front side of the steam drum, just below the low water mark, and extends approximately halfway across the shell. As the water rises from the front tubes, it strikes the baffling and is deflected downward, thus aiding in maintaining a good circulation.

When used in horizontal water-tube boilers, as shown in the longitudinal view of the Franklin water-tube boiler on another page, the baffle extends across the shell directly above the front header and below the dry pipe.

Due to the superior design of the modern steam boiler, there is little necessity for the baffle as an aid to circulation, its real value lying in preventing spraying near the steam outlet.



CONSOLIDATED SAFETY VALVE

AS THERE IS SOME confusion in the matter, it is well to get clearly in mind that the International Engineering Congress will be held in San Francisco in September, 1915, as planned. The International Electrical Congress has been postponed because of the impossibility of convening the International Electro-Technical Commission, under whose authorization that congress was to have been held, but this does not affect the International Engineering Congress, which is under the control of a Committee of Management, with W. F. Durand, Foxcroft Bldg., San Francisco, as Chairman, and E. J. Dupuy, Executive Secretary. Rapid progress is being made in the arrangements for the Engineering Congress, and the management expresses its desire for the earnest support of the whole engineering fraternity. Complete information can be had from the Executive Secretary, and it is desirable to send in subscriptions at an early date.

IT IS most satisfactory to have an authoritative method of determining safety valve sizes. Engineers and manufacturers agree that the conclusions of the committee of the A. S. M. E. should be put into universal use.

Dry Pipes and Domes

As dry steam can be obtained without them, they are expensive and they tend to weaken the shell; domes on boilers are less common now than formerly. The theory of the dome is that by taking steam farther from the surface of the water and by allowing a low velocity of steam as it rises into the dome, any water present will separate and drop back to the boiler; but with sufficient amount of steam space, dry steam can be easily obtained without this device.

The dome is usually cylindrical in shape, with a flat or bumped steel top riveted on and braced, or with a cast-iron top somewhat curved in section, and is generally placed in the center of the shell.

Ordinarily, the steam drum, which is a shell with dished ends and connected to the boiler by a steam nozzle, is used where 2 or more boilers are set in a battery, for receiving steam from the boilers, and serving as a reservoir from which the steam main is taken for the engines.

The accompanying tables give the required dimensions of domes and drums for various sized boilers.

TABLE I. DIMENSIONS OF MUD AND STEAM DRUMS

Diam. of boiler.....in.	48	54	60	66	72
Diam. of mud drum.....in.	14	14	16	16	20
Len. of drum for 2 boilers.....ft.	11	12	13	14	15
Len. of drum for one boiler set crosswise.....ft.	9	9.5	10	11	11.5
Len. of drum for one boiler set lengthwise.....ft.	5.5	5.5	6.5	6.5	7
Diam. of steam drum.....in.	30	30	24	30	30
Len. of steam drum, 2 boilers...ft.	7	7.5	8	8.5	9

The dry pipe is a large pipe the size of the steam main, carried inside the boiler shell, capped at the ends, and drilled with a number of small holes, causing the steam to enter in small jets at a low velocity so that water which may have been brought up with the steam will separate and drain back to the boiler. It is installed as shown in the various water-tube boilers, either at one end or the center of the shell. The dry pipe is inexpensive and avoids weakening the shell by making any extra large opening.

Superheaters

In order to reduce the loss by cylinder condensation of from 10 to 40 per cent of all heat supplied to the average reciprocating engine, steam is superheated before entering the cylinder.

In this country steam temperatures exceeding 500 deg. F. are seldom employed, while in Europe few, if any plants are installed without superheaters, with 600 deg. F. as a common working temperature, the difference being due to valve design. Experience has shown that with engines of ordinary design, the temperature at the throttle should not exceed 500 deg. F., this degree of superheating insuring practically dry steam at cutoff. Just how far superheating can be carried with a given engine of ordinary construction can be best determined by experiment, but a temperature of 450 deg. F. may be taken as a good average. Higher temperatures are apt to interfere with lubrication and may sometimes cause warping of the engine valves. With temperatures below 450 deg. F., no difficulties are ordinarily met.

The requirements for a successful superheater are security in operation, economical use of heat applied, protection of the joints from the fire, provision for free expansion, arrangement such that it may be cut out or repaired without interfering with the operation of the plant, and ease of application to existing plants.

Location

Superheaters may be divided into 2 general classes, those which are embodied in the boiler proper and the independently fired unit. In this country standard practice advocates the installing of the superheater in the boiler setting, preferably as near the fire as possible.

Independently fired superheaters may have their degree of superheat varied independently of the performance of the boiler; they can be placed at any convenient point and repairs can readily be made without shutting down the boilers. On the other hand, this type of superheater requires separate firing, extra attention, extra piping and extra space.

TABLE II. DIMENSIONS OF STEAM DOMES

Double Riveted Steel Shell and Heads, with Iron Rivets

Diam. of Boiler	Diam. of Dome	Height of Dome	Thickness of Dome Shell	Thickness of Dome Head
36	20	22	1-4	5-16
38	20	22	1-4	5-16
40	22	24	1-4	5-16
42	22	24	1-4	5-16
44	24	26	1-4	5-16
46	24	26	1-4	5-16
48	26	28	1-4	5-16
50	26	28	5-16	3-8
52	28	30	5-16	3-8
54	28	30	5-16	3-8
56	30	32	5-16	3-8
58	30	32	5-16	3-8
60	32	34	5-16	3-8
62	32	34	5-16	3-8
64	34	36	5-16	3-8
66	34	36	3-8	7-16
68	36	38	3-8	7-16
70	36	38	3-8	7-16
72	36	40	3-8	7-16

By referring to the longitudinal view of the Babcock & Wilcox boiler, the superheater may be seen to be located in the triangular space below the drums and above the inclined tubes, so that the entire first pass of the boiler heating surface is between it and the fire, avoiding any wide variation in the temperature of the gases sweeping over the superheating surface. This superheater is, as shown, supported by light angles and rods from above and by brickwork from below.

In the Stirling type of boiler, 2 kinds of superheaters are in use. One of these consists of 2 drums connected by seamless drawn tubes and placed so as to take the place of the middle bank of tubes, or it may be installed in the final pass of the gases in the back of the boiler. At the present time, the regular Babcock & Wilcox superheater is installed in all Stirling boilers and when so used is located between the triangular space beneath the center drum between the front and middle banks of tubes, allowing all the gases to sweep evenly over the superheating surface after they have passed over the front bank of boiler tubes.

In the vertical boiler, such as the Rust, the superheater may be placed in either one of 2 positions. When the superheat required is not in excess of 75 deg. F., the

superheater is placed at the top of the second pass between the vertical baffle and the rear bank of tubes. When a greater degree of superheat is desired, the superheater is placed toward the bottom of the first pass between the front bank of tubes and the vertical baffle, where its members are protected from the direct impinging of the gases of combustion by baffles.

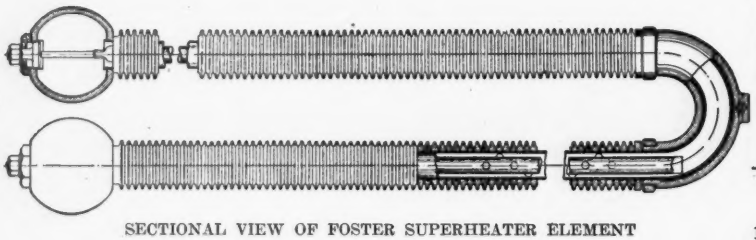
The Heine superheater is generally located at the side of the boiler shell toward the front and just above the last passage of the boiler gases. It is supported by special castings resting upon the boiler tile bar and brick setting.

On account of its compact form, the Foster superheater can be placed in location similar to the Babcock & Wilcox.

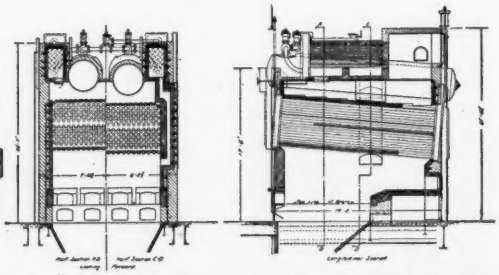
Size of Superheaters

No definite statement can be made relative to the size of superheater required for a given installation until numerous factors and local conditions are taken into account. The number of square feet of heating surface of a superheater depends upon the type and size of boiler and furnace, the quantity of steam generated; the degree of superheat desired; the location of the superheater; whether connected so as to create a counter or parallel flow of the steam to the flue gases; the material used in construction of the superheater. Various authorities state that the required number of square feet of superheating surface varies from 10 to 100 per cent of the boiler heating surface; although current practice indicates approximately 10 to 80 per cent.

From various installations, the following data has been obtained:



SECTIONAL VIEW OF FOSTER SUPERHEATER ELEMENT



HEINE SUPERHEATER AS APPLIED TO HEINE WATER TUBE BOILER

In the case of a Foster superheater with a Heine water-tube boiler and placed in the last pass, it was found that the superheater surface was 15 per cent of the boiler heating surface. A steam pressure of 200 lb. was carried and a superheat of 50 deg. F. was being maintained. The temperature of the flue gases at the entrance of the superheater was about 550 deg. F.

In another plant 2 Stirling water-tube boilers were in operation, one having a heating surface of 6000 sq. ft. and the other a heating surface of 7200 sq. ft. Placed between the first and second banks of tubes were 2 Foster superheaters having superheating surfaces of 465 and 550 sq. ft. each, respectively or, in each case a superheating surface 76 per cent of the boiler heating surface. Chain grate stokers burning Illinois screenings were being used and a steam pressure of 200 lb. gage carried. The steam was superheated 110 deg. F.

The third plant had water-tube boilers and superheaters delivering steam at a temperature of 570 deg. F. under a gage pressure of 175 lb. The boiler heating surface was 5200 sq. ft. and the superheating surface 660 sq. ft., or approximately 12 per cent of the boiler heating surface.

A large central station contains water-tube boilers having a heating surface 5 times greater than that of the superheater. In this case, the boilers are Babcock & Wilcox, having superheaters placed in the triangular space between the tubes and shell. Chain grate stokers are used, a steam pressure of 210 lb. gage carried and the steam superheated 225 deg. F.

In the fifth plant, a European station, the superheater surface was 1450 sq. ft. and the boiler heating surface 4400 sq. ft., the former being nearly 33 per cent of the latter.

Operation

Superheaters require practically no attention whatever during operation, the only time special care is required is during the starting up and cutting out periods.

In some types of superheaters, it is found necessary, while raising steam in the boilers, to protect the members, either by diverting the hot gases (by dampers) or, as is usually done, by connecting the superheaters to the water space of the boilers and flooding the superheater, causing it to act as a part of the boiler. In order to do this, it is necessary to open and close certain valves on each boiler, which operation must be reversed when the steam is up to the desired pressure and the superheater is to be placed in service. The superheater must then be thoroughly drained, which must be done with great care, because of the disastrous results to the engines or turbines, should the entrained water be forced into the steam pipes. Another disadvantage of flooding is the liability of the superheater to gather scale.

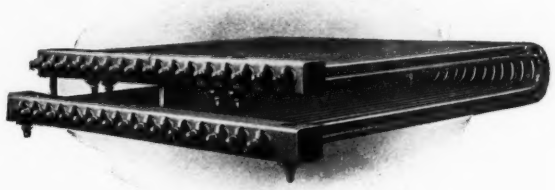
As described in the following paragraphs, most modern superheaters are so constructed that during the time steam is being raised, no flooding is necessary. The superheater members are left empty and as soon as the steam in the boiler has reached the desired pressure, it is passed through the superheater, out into the steam header and mixed with the saturated steam in the proportions necessary to produce the desired degree of superheat.

Construction and Forms

Most superheaters are constructed either of wrought iron, mild steel, cast iron or cast steel, the latter material having the advantage of not being damaged by any temperature to which it is likely to be subjected. Cast metal superheaters are usually ribbed, like the cylinder

of an air-cooled gas engine, and are, therefore, heavy and thick-walled, necessitating a higher temperature for the same useful effect than the wrought-iron construction, but minimizing the fluctuations of steam temperature which would otherwise be caused by wide variation in furnace temperature. One of the most successful cast-metal heaters is of European design and is constructed of a special alloy known as "Schwoerer" iron.

Wrought iron and mild steel offer the advantages of

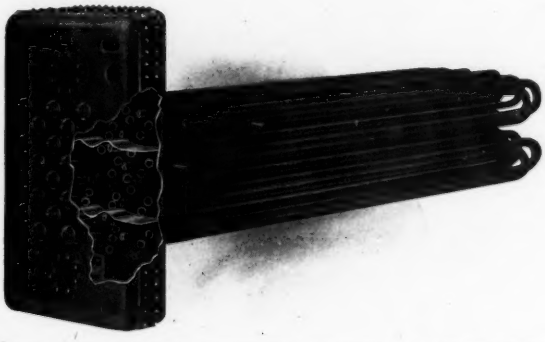


BABCOCK & WILCOX SUPERHEATER AS APPLIED TO BABCOCK & WILCOX BOILERS

lightness, ease of construction, and low first cost, but cannot be exposed to very high temperatures without injury, consequently provision must be made for diverting the direction of the heated gases or for flooding the coils while steam is being raised.

The Foster Superheater

This consists of a series of straight elements, generally arranged in parallel rows and joined at one end to manifolds or connecting headers. At the other end are return bends unless great accessibility is desired



HEINE SUPERHEATER SHOWING INTERNAL CONSTRUCTION

when return headers are substituted. The elements, as shown, consist of straight, seamless, drawn steel tubes, on the outside of which are fitted a series of cast-iron annular gills or flanges, placed close to each other and carefully fitted to the tube so as to be practically integral with it. The rings or annular gills are carefully bored to gage and shrunk on the tubes and as the coefficient of expansion of the steel tubes is a trifle greater than that of cast iron, the rings grip the tubes even tighter when in service.

Inside of the elements are placed other tubes of wrought iron, closed at their ends, and centrally supported by means of knobs or buttons regularly spaced throughout their length, forming a thin annular passage for steam between the inner and outer tubes, bringing the steam close to the heating surface so that it is quickly heated. The joints at the ends of the elements are made by expanding the steel tube into wrought-steel or cast-steel headers.

This superheater, due to the heavy protection given it, requires no flooding. It is made by Power Specialty Co., of New York.

The Babcock & Wilcox Superheater

This is formed of 2 transverse, square, wrought-steel boxes or manifolds into which 2-in. cold-drawn, seamless-steel tubes, bent to a "U" shape, are expanded. By variation in the length and number of these tubes, the requisite amount of heating surface and cross-sectional area for the flow of steam are provided. Ordinarily, the tubes are arranged in groups of 4 and opposite the ends of each group an elliptical handhole is provided for expanding or inspection. The handholes are machine faced and milled back from the inside edge of the box a sufficient distance to make a seat, and are closed on the inside by forged steel, handhole plates held in position by fixed studs and forged steel binders and nuts, the joints between the boxes and plates being made with thin gaskets.

PARKER SUPERHEATER

In the early design of the Babcock & Wilcox superheater, a flooding device was always used. But the makers of this superheater, the Babcock & Wilcox Co., of New York, have found that this device is not necessary and as a result supply it only as an extra means of protection.

Cores are sometimes used in these superheaters, but only in special construction where their employment leads to a better steam distribution than would be ob tained without their use.

The Heine Superheater

This consists of a header made of flange steel plate, into one side of which are expanded 1½-in. seamless, drawn, mild steel U-tubes, with a series of handholes opposite in the other sheet, giving ready access to the interior. In order to direct the flow of steam through the tubes, the header is, by means of light, well fitted sheet-iron diaphragms, divided into 3 compartments.

Depending upon the capacity and degree of superheat desired, the Heine superheater may be single and placed on one side of the boiler shell toward the front and just above the last passage of the flue gases, or it may be in 2 parts, one on each side of the boiler. By means of a regulating damper, the circulation of gases may be controlled and the degree of superheat thus varied as desired, or the superheater may be cut out of service entirely, and as soon as the heat from the gases is absorbed, only saturated steam delivered.

This superheater is made by the Heine Safety Boiler Co., of St. Louis, Mo.

THE PARKER SUPERHEATER

AS SHOWN in the illustration, this consists of bent steel tubes connecting at the ends to cast steel headers, the whole being placed in the combustion chamber back of the furnace, or directly above the rear grate in double ended boilers. Steam passes from the boiler drum downward into the lower header of the superheater, through the superheater tubes to the upper header and from there into a reservoir drum which holds sufficient condensed steam to protect the superheater in starting. Surplus water drains automatically into the boiler.

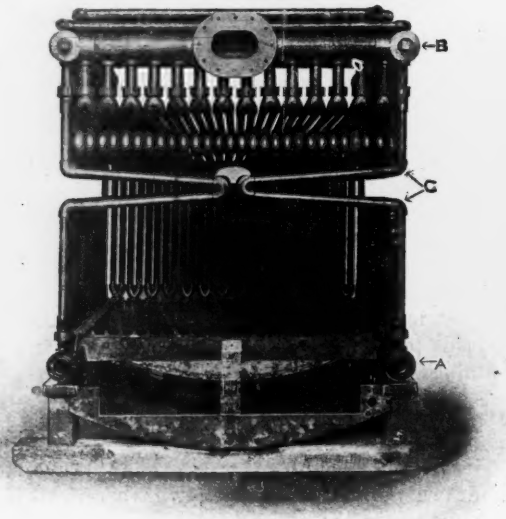
The manufacturers of this superheater, the Parker Boiler Co., of Philadelphia, allow about ¼ sq. ft. of superheating surface per boiler horsepower, which gives about 100 deg. superheat for all loads.

Water-Tube Boiler Details

Almy Boiler

THIS sectional water-tube boiler, as made by the Almy Water-Tube Boiler Co., of Providence, R. I., was designed for a maximum of power within a minimum space, and while it is to some extent used for stationary work, its greatest field of usefulness is in marine service.

This boiler consists of an upper and lower manifold, side, fore and aft sections, feed water heater, steam dome and water reservoir, grates and casing.



FRONT VIEW OF ALMY WATER-TUBE BOILER SHOWING ARRANGEMENT OF TUBES

Water enters the heater at the top, passes through the heater tubes and enters the horizontal reservoir, at the middle of which the water level is generally maintained. It then passes through the downflow tubes into the lower manifold, up through the generating tubes, through the top manifold and into the separator as steam, which is taken out of the highest point in the dome, resulting in the delivery of dry steam.

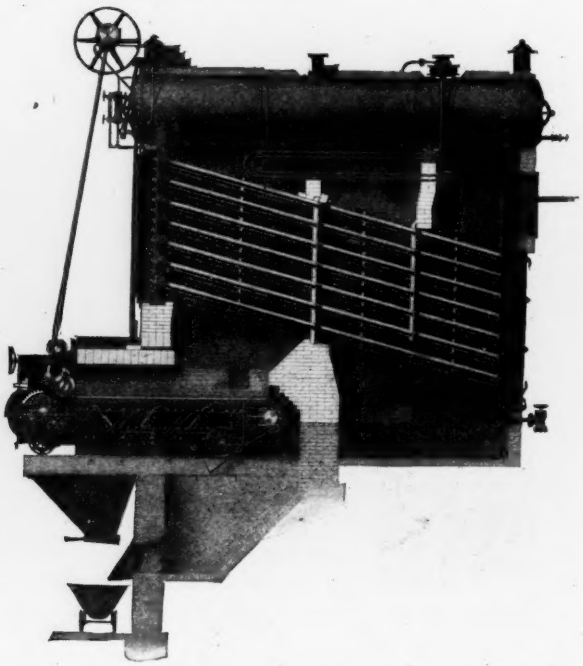
The blowoff is connected to the mud drum, which is a part of the lower manifold, and located near the center at the rear of the furnace.

Babcock & Wilcox Boilers

THESE BOILERS are built by the Babcock & Wilcox Co., of New York, in 2 classes, the longitudinal-drum type and cross-drum type, the former of which is the generally accepted standard and the one which will be here described.

This boiler has a heating surface made up of a drum or drums, depending upon the width of the boiler. To these are connected through cross boxes at either end, the sections of which are made up of headers and tubes. At the lower end of the rear sections a mud drum extends across the setting and connects to all sections by short tubes expanded into bored seats.

In this boiler tubes are expanded into headers of serpentine form, giving a staggered arrangement when assembled as a complete boiler. These headers are of either wrought steel or cast iron and may be vertical or inclined, as desired. Opposite each tube end in the headers is placed a handhole of sufficient size to permit the cleaning, removal or renewal of a tube. To facilitate cleaning of the drums, all heads are provided with manholes, all manhole and handhole plates being of forged steel turned to fit the openings and held in position by forged steel guards and bolts.



SIDE VIEW OF BABCOCK & WILCOX BOILER EQUIPPED WITH CHAIN GRATE STOKER AND SUPERHEATER

Beneath the tubes the space between the bridge wall and the rear boiler wall forms a pocket into which much of the soot is deposited and from which it may be readily cleaned through doors provided for the purpose. Small dusting doors provided with self-closing shutters are supplied for the side walls, through which the tubes may be cleaned of soot, either by portable or permanently installed blowers.

Boilers of the longitudinal type are suspended front and rear from wrought iron or steel supporting frames entirely independent of the brickwork, allowing for easy

repair of the brickwork, and expansion and contraction of the pressure parts without straining either boiler or brickwork.

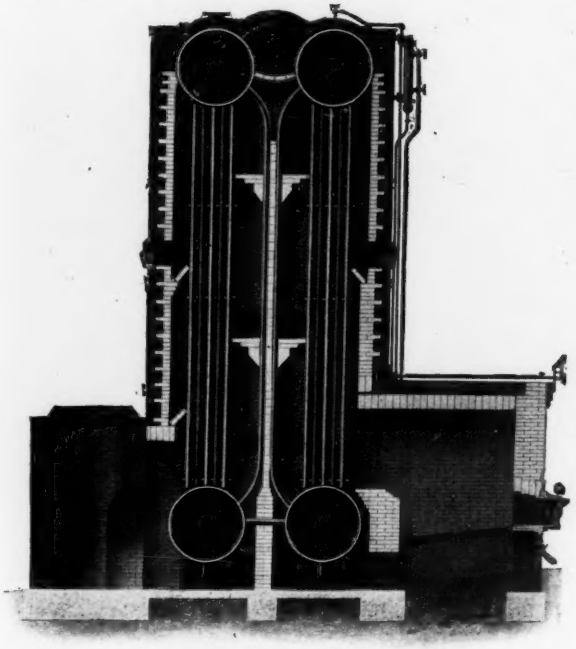
Entering near the front and bottom of the drum or drums, feed water passes to the rear of the drum, downward through the rear circulating tubes to the sections, upward through the tubes of the sections to the front headers and through these headers and front circulating tubes again to the drum, where such water as has not been formed into steam retraces its course. Steam collects in the space above the water line from which it is drawn through a collecting pipe.

Each drum is provided with a pop safety valve, usually at the middle third section. The blowoff or blowoffs, depending upon the width of the boiler, are connected to the bottom of the mud drum.

In ordinary construction, furnace gases are led over the heating surface by baffles formed of cast-iron baffle plates lined with special firebrick and held in position by tube clamps.

The Rust Boiler

THIS BOILER, of the vertical water-tube type, consists of transverse steam-and-water drums and 2 transverse water-and-mud drums, set parallel and connected by 5 rows of straight vertical tubes and in some types, by an additional row of curved tubes. The upper steam-and-water drums are connected by one row of short



ELEVATION OF RUST WATER-TUBE BOILER

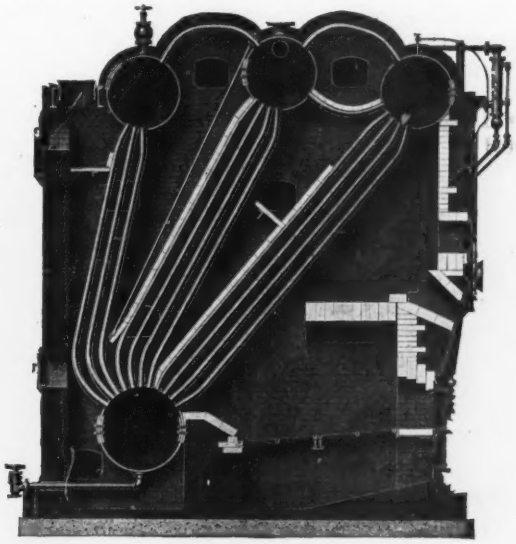
circuiting tubes below the water line and by another row of connecting steam tubes above the water line. The water-and-mud drums are connected by a row of short horizontal circulating tubes.

To facilitate internal cleaning, inspection and repair, one end of each drum is provided with a manhole, plates of which are of forged steel and swing inward upon a lug riveted to the inside of the drum head. By means of a bumped tube sheet, a drum is provided which is in every way as strong as those in which the tubes enter radially.

Feed water enters through the upper side of one head of the rear water-and-mud drum. A blowoff connection is placed at the center of the bottom of each water-and-mud drum.

As shown in the illustration, the vertical baffle wall built up from the ground and located centrally between the main banks of tubes permits the water-and-mud drums to be supported free of all brickwork without the possibility of any gases short-circuiting to the stack. A covering of firebrick is carried on the circulating tubes, forming a roof for the passage of the gases, which cross the tubes 8 times in passing from the furnace to the chimney with a resulting thorough mixture and highly efficient heat transfer to the water.

Four large cast-iron saddles, resting on masonry foundations, one saddle being placed under each end of each water-and-mud drum support the boiler. This boiler is provided with a dutch oven furnace which may be equipped with any make of stoker.



SIDE VIEW OF STIRLING WATER-TUBE BOILER

It is difficult for scale or soot to adhere to the vertical tubes, and as a result tend to fall to the bottom, where they are readily removed. Cleaning doors for the removal of flue dust are placed at the bottom of the setting, and in the side are dusting doors through which a steam soot blower may be inserted. Additional inspection and cleaning doors are built into the setting.

The Rust boiler is built by the Babcock & Wilcox Co., of New York, N. Y.

Stirling Boilers

THIS BOILER, made by the Babcock & Wilcox Co., has 3 horizontal steam drums and one horizontal mud drum, connected by a series of inclined tubes which are bent at the ends to permit them to enter the drums radially. Short tubes connect the steam spaces of all the upper drums and also the water spaces of the front and middle drums. Each drum has a manhole at the end to allow for cleaning and inspection.

Suitably arranged fire-tile baffles between the banks of the tubes direct the gases in their proper course.

Stirling boilers are supported by the upper drums resting on a structural steel framework and the lower drum in saddles on the foundation proper.

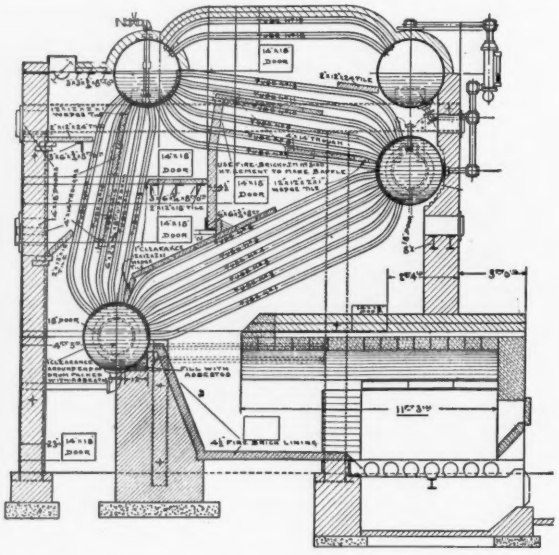
Feed water enters the rear upper drum, which is the coolest part of the boiler, discharges in a removable trough, and flows down the rear bank of tubes to the bottom or mud drum, where it is so heated that many of the impurities are precipitated. There is a rapid circulation up the front bank of tubes to the front drum, across to the middle drum, thence down the middle bank of tubes to the mud drum. At the center of the upper drum, steam connection is usually made and on each side of this steam outlet is located a pop safety valve.

One or more connections for blowoff, depending upon the size of the boiler, are placed at the bottom of the mud drum and extended through a sleeve in the rear or side wall, outside of which the blowoff valve is located.

Badenhausen Boilers

BADENHAUSEN CO., of Philadelphia, are the manufacturers of a boiler which is claimed to give continuous and unrestricted circulation.

This is a water-tube boiler of the 4-drum type, 2 water drums and 2 steam drums, so constructed that the 2 water drums and the rear steam and water drum are connected by tubes to give a perfect cycle of circulation.



ELEVATION OF BADENHAUSEN BOILER

The steam drum is connected through the water column opening to the lower front drum. All tubes are seamless, enter the drums radially and are expanded and properly flared.

Feed water enters this boiler by means of a pipe passing through the top of the rear drum to below the water line, while the blowoff is located at the lowest point in the lower drum. Connections for steam and safety valve outlets are on top of the steam drum.

Baffling of this boiler forces the gases to pass all of the tube heating surface, resulting in high efficiency.

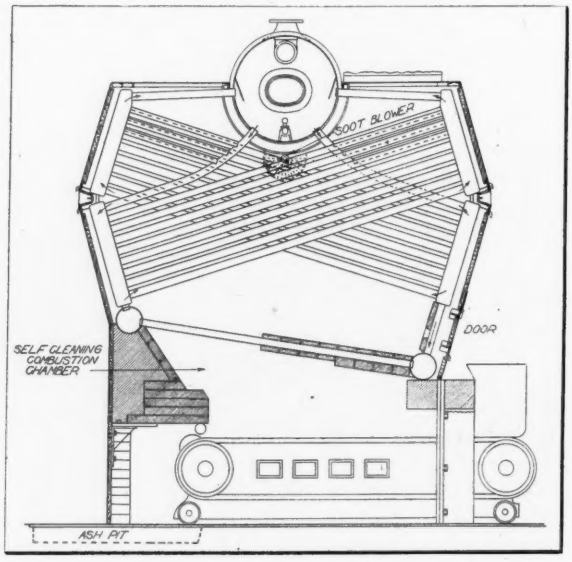
Internally, this boiler is easily cleaned by removing 4 manhole covers, one being located at the end of each drum, and inserting a water or air driven turbine cleaner. For the removal of soot from the heating surfaces, clean-out doors are placed at convenient points in the settings.

The boiler is supported by steel framework built up of I beams, the rear steam-and-water, and the steam drums resting on horizontal I beams, the water drum being suspended from heavy turned bolts secured to these beams, while the mud drum is suspended from those tubes connected to the rear steam and front water drums.

Furnaces for these boilers may be arranged for hand or any make of stoker firing.

Worthington Sectional Boilers

THE WORTHINGTON water-tube boiler consists of a transverse water and steam drum with alternate obliquely set banks of tubes, joined by headers, the upper parts of which connect to the side of the drum, while the lower side of the lower header terminates in a mud drum extending through the casing. The headers are placed so closely that they form a complete enclosure, regardless of the sheet-iron casing. Opposite the end of each tube in the header is a handhole of proper size to admit cleaning, removing or replacing of tubes, the opening being fitted with a cap held in place by a forged clamp bolt.



WORTHINGTON BOILER AND SETTING

Feed water enters through a pipe passing into one end of the drum to a point about midway its length, and discharges below the water line.

Two steam outlets are placed at the top of the boiler, and the blowoff connection at the bottom of the front mud drum, which is set, as shown in the accompanying illustration, somewhat lower than the rear mud drum. These mud drums are then connected by a row of tubes inclined toward the front and supporting a flat ignition arch forming a reverberatory furnace.

On top of the main tubes and beneath the steam drum is provided a self-cleaning soot blower having small jets in line with the space between each section, so that, when the blower is moved backward and forward, the soot is blown down and carried over with the ashes to the pit below.

The Worthington boiler construction shows 2 distinct boilers connected to the steam drum with alternate sections of tubes expanded therein, and the steam delivery is such that each section has its own outlet of the steam made in that particular section, therefore insuring dry steam.

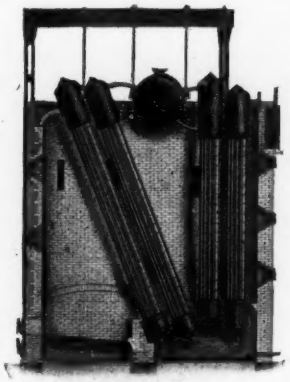
Capacity of this boiler in horsepower per cubic foot is large, a 300-hp. unit measuring but 14 ft. 6 in. from front of grate to rear of boiler; 9 ft. 7 in. over all in width and 15 ft. 9 in. in height from floor line to top of steam drum.

Worthington boilers are handled by James Beggs & Co., of New York.

Bigelow-Hornsby Water-Tube Boiler

IN THE standard Hornsby boiler, as manufactured by The Bigelow Co., of New Haven, Conn., may be found 16 units connected to a transverse water and steam drum which extends the entire width of the boiler. Eight of the units, each consisting of a water-and-mud drum directly beneath a water-and-steam drum and connected by means of straight tubes expanded in the heads of the drums, are set in a vertical position, 4 in a row, in the rear of the transverse water-and-steam drum. The other 8 unit drums, also 4 in a row, are set in front of the transverse drum but in an oblique position.

Steam spaces of all the drums are interconnected by nipples of seamless drawn steel tubing, and the water spaces of the upper drums of the second and third row of units are connected to the water space of the transverse drum.



THE BIGELOW-HORNSBY BOILER

The drum of each unit is provided with a manhole at its head, while the transverse drum has a manhole on the top, thus rendering it easy to inspect or clean the boiler.

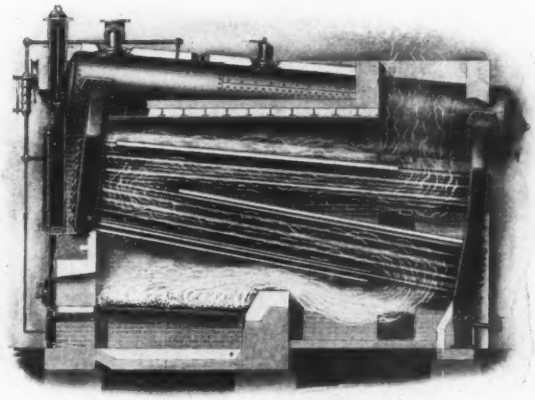
Pressed steel safety valve and steam outlet nozzles are on the highest part of the transverse drum. Feed water enters through the connection made near the top of the rear drums, just below the water line, while the blowoff connections are made at the bottom of the second and fourth sets of water-and-mud drums. As these are the lowest points in the boiler, this double connection is capable of thoroughly draining the entire boiler.

Assuming that thin streams of gases passing over the heating surface are an important factor in rapid heat transfer, passages for the gases have been made as narrow as possible, but frictional resistance is low because the path of the gases from furnace to stack is direct and of ample area, the openings between the tubes extending their entire length.

The boiler proper is suspended by steel rods attached to lugs, riveted to the various steam and water drums, and hung on built up girders resting on structural columns. This boiler can be used in connection with both hand and stoker fired furnaces.

Casey-Hedges Boiler

THE GENERAL construction of this boiler is a drum with parallel water tubes, which are divided into 2 banks, an upper and a lower, the upper bank and the drum being inclined 1 in. to the foot and the lower bank inclined 2 in. to the foot. One manhole in the rear drumhead and a handhole opposite each tube in the headers are provided, allowing ready access for cleaning, inspection and repairs. The boiler is ordinarily supplied with a combination structural steel and cast-iron front, from which, by means of a link riveted to the drumhead, the front end is supported, the rear header resting on rollers.



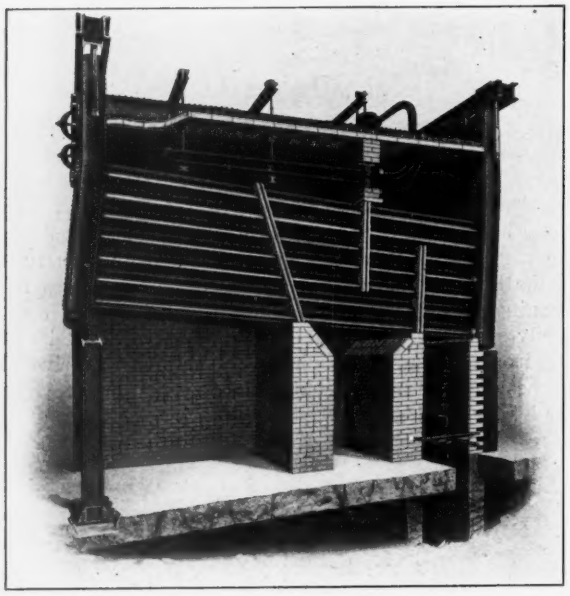
SECTIONAL ELEVATION OF CASEY-HEDGES WATER-TUBE BOILER

The feed water is discharged into a mud drum located at the bottom and rear of the drum, while blowoff connections are made at the bottom of the drum and also at the bottom of the rear header. A combination dry pipe, steam outlet and safety valve connection is placed near the front drumhead.

This boiler is made by The Casey-Hedges Co., Chattanooga, Tenn.

Edge Moor Boilers

EDGE MOOR water-tube boilers are built up of 4 sections, the drums, front and rear headers, and the tubes. The drums enter the headers at their full area to which they are connected by flanges, avoiding the necessity of cutting the drums, and creating a solid steam and water connection between all drums without the use of outside connections. Slanting tubes are expanded into the inner side of the lower part of the headers and opposite each tube in the outer plate of the header, is a flanged oval handhole, closed by an oval internal cover. Opposite each drum is a manhole opening flanged inward and surface machined. Steam outlet and safety valve connections are located at the top of the front header, while at the bottom of the rear header is the blowoff.



SIDE VIEW OF EDGE MOOR WATER-TUBE BOILER

The boiler is hung from columns at the front end (and supported upon expansion rollers) at the rear, the arrangement being such that any style of mechanical stoker or shaking grate can be used.

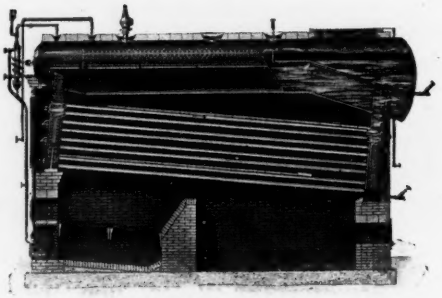
The Edge Moor Iron Co., Edge Moor, Del., makes this boiler.

Erie City Boilers

ERIE CITY horizontal water-tube boilers consist of one or more horizontally set steam drums, to each end of which are attached large vertical water legs, perforated to receive staggered pairs of tubes. One end of the drum is provided with a manhole while elliptical handholes are placed opposite each pair of tubes, a construction which tends to reduce the amount of labor required in cleaning or repairing.

Brackets riveted at the bottom of the water legs, take the weight of the boiler, rollers being placed under those at the rear to permit of expansion and contraction.

Feed water is led into the forward end of a pan which forms an inclined partition, fixed in the rear end of the steam drum and extending from the water level to the rear head of the drum, downward and backward from side to side, and is well mixed with the contents of the pan, absorbing much heat before entering rear water leg. From this pan, the blowoff of the boiler is led. Flanged steam and safety valve outlets are centrally located on top of the drum, while a blowoff is connected to the bottom of the rear header.



ERIE CITY WATER-TUBE BOILER

The Erie City Iron Works of Erie, Pa., also manufactures a vertical water-tube boiler consisting of 2 transverse drums, set parallel and one directly above the other and connected by tubes entering the shells radially. The upper drum rests in saddles supported by steel framework, while the lower drum hangs from the tubes above. A manhole is placed in the shell of the upper drum and one in the head of the lower drum, each being provided with a heavy pressed steel plate. Feed water enters the lower drum, is distributed through a double discharge, and is then taken up through the front bank of tubes, while a blowoff is placed at the bottom of the lower drum. One return and 2 safety valve outlets are located on the top of the upper drum.

These boilers may be set in either brick or steel casings.

Franklin Water-Tube Boilers

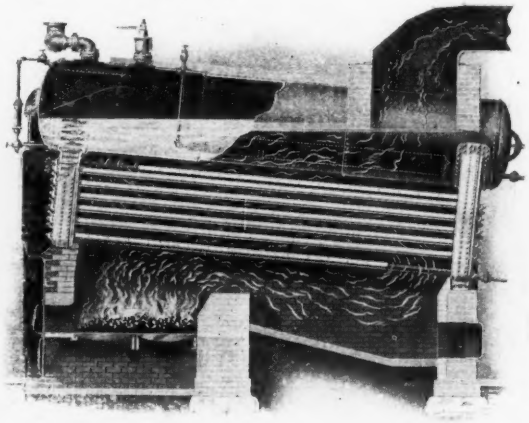
THE FRANKLIN water-tube boiler consists of a horizontally inclined steam drum with water tubes extending between headers riveted to steam drum. The headers are braced with hollow staybolts of seamless steel tubing, making it possible to blow the soot from the tubes whether the boilers are set singly or in battery without the necessity of openings in the side walls.

The front end of the boiler is supported by a heavy cast steel lug riveted to the front head of the steam drum and resting upon a heavy cross girder supported by columns forming part of the front. While ordinarily the rear end rests upon shoes and rollers supported by a low wall, it can readily be adapted to column suspension if desired.

The feed pipe enters a large mud drum, where it discharges the water at the rear end, and any sediment present is precipitated where it can easily be blown out through the direct blowoff in the rear of the steam drum, the water returning to the front end of the mud drum before being set free in the boiler. There is also a second

blowoff in the bottom of the rear header. Dry steam is insured by a large deflecting plate as well as a dry pipe having a large number of small holes.

Horizontal baffles are used entirely, being easily kept clean by means of the soot blower through the hollow staybolts and easily accessible and inexpensive for replacement when necessary.



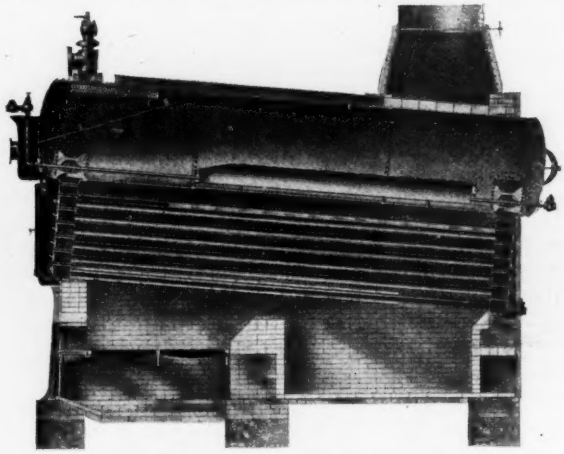
ELEVATION OF FRANKLIN WATER-TUBE BOILER

Boilers are made up in units of a size which can be transported on railroad cars so that the boilers can be built complete and tested in the works before shipment.

Franklin water-tube boilers are built by the Nagle Engine & Boiler Works at Erie, Pa.

Heine Boilers

THE Heine water-tube boiler, manufactured by the Heine Safety Boiler Co., of St. Louis, Mo., consists of 3 main parts, the shell, water legs and tubes.



SIDE ELEVATION OF THE HEINE WATER-TUBE BOILER

In the bottom of the cylindrical shell, near each end, is cut the throat opening for the internal connection of the water legs, between which extend the tubes. These are held in position by being roller expanded and slightly flared to increase their holding power.

Inside and parallel to the shell near the bottom is fastened a sheet-steel mud drum, which is entirely closed with the exception of a small opening at the top near the front end. The feed pipe, which passes through the front head of the shell, enters the front end of the mud drum near the bottom, while a blowoff connection which passes through the bottom of the rear head of the shell connects with the back end of the mud drum near the bottom.

Over the throat opening at the front end, slanting upward and closely fitted to the front head and to that portion of the circumference of the shell with which it comes in contact, is placed a sheet-iron deflection plate, and above this, just beneath the steam opening, is fastened the dry pan, in the sides of which are a large number of perforations. The main steam outlet is located near the top of the shell near the front end, and the main blowoff is placed in the center at the bottom of the rear water leg handhole sheet.

One manhole for ready inspection and cleaning is located in the rear head of the shell, while handholes are provided opposite each tube in the handhole sheets of both the front and rear legs, so that mud and scale can easily be removed from the straight tubes by cleaner and hose.

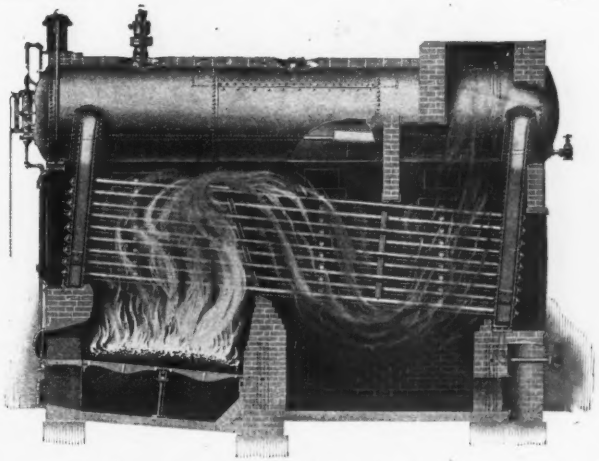


FIG. 1. KEELER WATER-TUBE BOILER

All cleaning operations and also the removal and replacing of tubes can be done by men standing erect and, therefore, in a convenient, comfortable and expeditious manner.

When set up for service, the Heine boiler inclines downward to the rear in the ratio of 1 in 12.

Heavy cast-iron columns support the front end, while the rear end rests on rollers which, in turn, bear on iron plates set in the top of a brick wall forming a portion of the setting. When used in connection with some forms of stokers, this form of support is somewhat modified.

On the lower row of tubes, extending back within 4 or 5 ft. of the rear end and on the upper row of tubes extending from the rear to within 3 or 4 ft. of the front end is placed the firebrick baffle tiling.

Hollow staybolts are utilized for blowing soot and dust from the tubes, while cleaning doors on each side of the shell provide access to remove any dust or soot which may settle over the upper tiling and beneath the shell.

Keeler Boilers

E. KEELER Co., of Williamsport, Pa., manufactures a horizontal water-tube boiler built up of one or more steam and water drums to which are riveted front and rear wrought-steel headers connected by straight, horizontal and staggered vertical rows of tubes inclined 1 in. to the foot. The drum is horizontal with a feed water inlet and a manhole at the front head, a steam outlet at the center and a safety valve near the front. Handholes are cut in the outside sheet of each header, opposite each tube. Feed water enters through a pipe passing through the front drumhead and is discharged into a

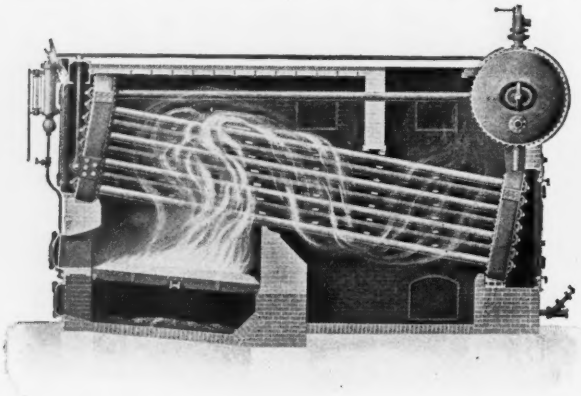


FIG. 2. KEELER CROSS-DRUM BOILER

mud drum in the rear. Two blowoffs are provided, one of these being connected to the mud drum, the other to the bottom of the rear header.

At the front end, support is obtained by means of a round-iron loop passing around the drum, hung from a supporting frame, while at the rear plates and rollers allow longitudinal movement.

Cleaning doors are placed in the sides of the settings.

Horizontal baffles of fire brick are provided where required to meet conditions imposed by local smoke ordinances.

Milne Water-Tube Boilers

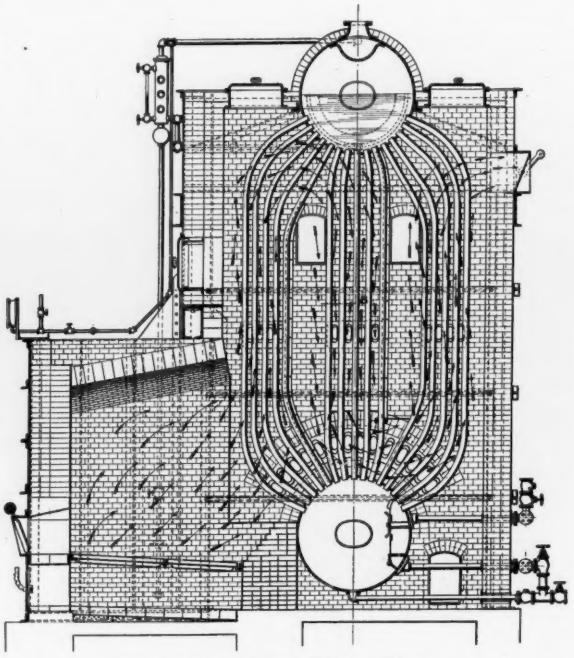
TWO TRANSVERSE drums, one set directly above the other and joined by radially-entering tubes, comprise the Milne water-tube boiler manufactured by The George T. Ladd Co., of Pittsburgh, Pa.

The boiler is supported by a structural steel frame entirely independent and outside of the brick work, the front wall being carried on a hollow air cooled girder, relieving the arches of all load.

Feed water is taken through a readily accessible feed chamber into the 2 rear banks of tubes, where the heat precipitates the scale-making substances, which gravitate back to the feed box, from which they can be blown, when necessary, thereby maintaining internal cleanliness.

All tubes are bent to the same radius and can be used end for end. For the largest boiler but 7 different kinds of bent tubes are required. The tubes are laid out in alternate wide and narrow alleys oblique to the axis of the drum, presenting a staggered form of passage to the gases, permitting of easy tube renewal and avoiding a direct rush of gases between rows to the baffle.

By reason of the method of suspension, steel plated furnace sides, absence of embedded members in the brick work, and cleaning doors seated upon asbestos strips, practical freedom from air leaks is secured. Circulation is unrestricted and ample liberating area, to-



SIDE VIEW OF THE MILNE BOILER

gether with adequate steam and water storage, is provided. High arches give large combustion space and the setting is free from dead areas. The boiler is standardized in sizes ranging from 125 to 1000 hp., as illustrated, and to 2000 hp. in the multidrum type.

Morrison Boilers

THE MORRISON BOILER Co., Sharon, Pa., builds this boiler. It consists of one or more elements or sections, each section being composed of a vertical bank of tubes connecting top and bottom drums. The tubes enter the drums radially and are so spaced that all alley ways are of equal width, thus securing uniform heat distribution and eliminating the usual large alley ways with their required baffles.

Equalizing tubes cross connect the various elements at top and bottom drums, and the top drums may be connected by means of a common header, thus readily enabling the building up of as many elements as desired. The dutch oven type of furnace is used and is usually placed at the end of the drums so that the circulation is lengthwise of the drums, thus securing the advantage of large area in the horizontal flow passage ways.

The boiler can be fed at the top or bottom, as required by local conditions; is supported in saddles under the bottom drums or hung by the top drums; and can

be furnished in 2, 3 or 4 pass style. Only standard shapes of brick are used, and the baffling walls are especially substantial, being built 9 in. thick. Tubes

FRONT VIEW OF MORRISON WATER-TUBE BOILER

may be removed without disturbing other tubes or baffles. Any style of grate or stoker may be used with this boiler.

O'Brien Boilers

JOHN O'BRIEN Boiler Works Co., of St. Louis, Mo., manufactures 3 types of water-tube boilers, horizontal designs A and B and a vertical unit design A is made of one or more combined steam and water drums riveted to the water legs or headers which are connected by banks of 3½-in. tubes. The drums are parallel to the tubes and when installed, the whole is inclined toward the rear 1 in. to the foot. Horizontal baffling arranged for either 2 or 3 passes is used, while a box tile is employed on the lower row of tubes producing an effect similar to the dutch oven setting.

The general construction of design B is similar to that of design A, except that the steam and water drums are set horizontal while the tubes incline the same amount as in the other boiler. In this boiler, vertical baffles, arranged for 3 or 4 passes, are used.

In both designs, feed water enters by means of a pipe passing through the bottom of the front drum head and discharges into a mud drum; the blowoff connection is at the bottom of the rear header, the steam outlet is located at the top of the middle third of the drum while the safety valve is placed at the top near the front.

For access to these boilers, one manhole in the rear drum head and handholes opposite each tube opening are provided.

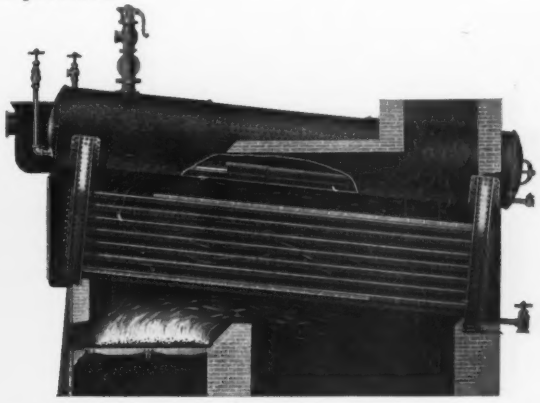


FIG. 1. O'BRIEN WATER-TUBE BOILER, DESIGN A

The vertical boiler of this company's make consists of 2 transverse drums, an overhead or steam and water drum, and a lower or mud drum joined by 3 banks of

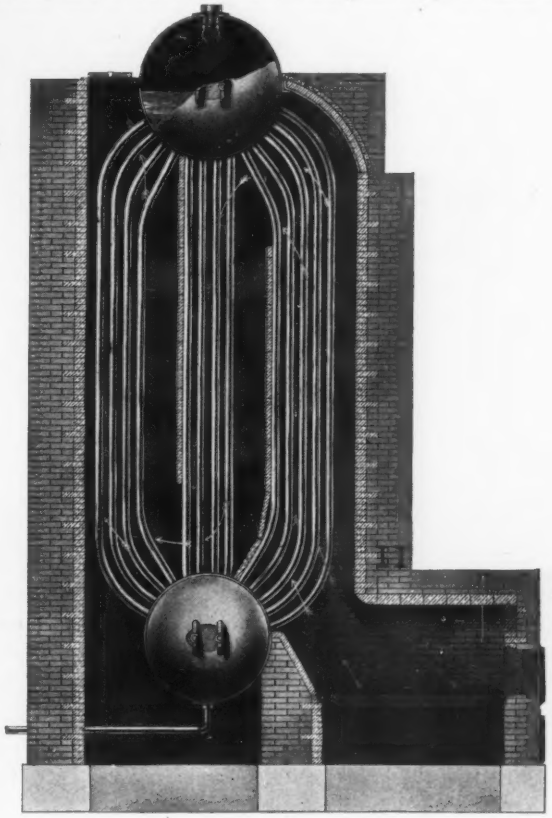


FIG. 2. O'BRIEN VERTICAL WATER-TUBE BOILER

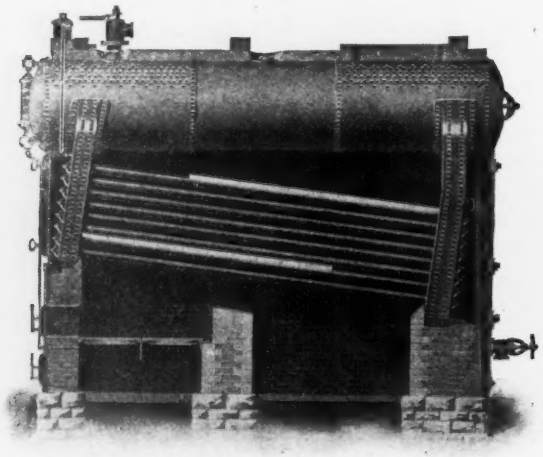
seamless tubes all entering the drums radially. Each tube is so placed as to be easily removed without interfering with any other.

Geary Water-Tube Boiler

A BANK of straight, staggered and inclined tubes is expanded at each end into box-shaped wrought-iron or steel headers, strongly braced and stayed. The back header is made longer than the front, so that the drum or drums connecting the 2 headers are level, and to avoid contraction of area in the course of circulation, the connection between the headers and the drum is made as large as possible.

All drum heads are dished to a radius equal to the diameter of the drum and are riveted to the shell, the front head having a steel flange for steam connection and flat seats for water column connections. On top of the drum, centrally located, is placed a pressed steel flange for the main steam outlet; while directly in front of this is a like connection for the safety valve. Inside of the steam outlet is a perforated dry pipe, an arrangement eliminating the use of internal baffles or deflecting plates.

One manhole is located in the rear head of each drum and handholes are placed in each header sheet opposite each tube opening, giving ready access to the interior of the boiler for cleaning and repairs. Both headers, consisting of 2 plates, flanged and joined by a butt strap, are stayed with hollow screwed stay bolts.



SIDE VIEW OF GEARY BOILER

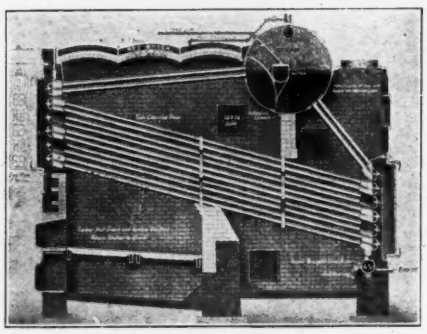
Feed water is introduced through the front head and conveyed by a pipe through the lower part of the drum and discharged just above the opening of the rear header. This pipe acts as a heater and purifier, tending to precipitate most of the scale-forming properties in the rear header.

Blowoff connections are placed in the bottom of the rear header, avoiding the use of any independent mud drum. Horizontal or vertical baffling is supplied as desired, and soot dusting plates placed at convenient points in the setting. To allow of independent boiler and setting expansion, the Geary boiler is suspended at the front end from overhead-cross channels by wrought-iron loops placed under the drums in front of the header, and is supported at the rear end by resting the rear header on rollers, which bear on heavy cast-iron plates, firmly supported by the brickwork of the rear wall of the setting. Joints between the brickwork setting and the headers are made with asbestos rope.

The Geary water-tube boiler is manufactured by the Oil City Boiler Works, Oil City, Pa.

Springfield Water-Tube Boiler

THE SPRINGFIELD water-tube boiler, made by The Springfield Boiler & Manufacturing Co., of Springfield, Ill., consists of a transverse water and steam drum placed above and connected to a slanting bank of straight tubes. To allow the furnace gases to surround them completely, these tubes are staggered by means of serpentine sectional headers. Both headers are vertical, the front one suspended, while through the mud drum the rear header rests on a plate and rollers, allowing for expansion and contraction. For internal cleaning, manholes are placed



SPRINGFIELD WATER-TUBE BOILER WITH TRANSVERSE WATER AND STEAM DRUM

at the ends of the drums and one handhole opposite each 4 tubes opening in the header, while, for the use of soot blowers, dusting doors are placed at convenient points in the settings.

The feed line enters the front of the drum and discharges into a feed pan located centrally therein, while the blowoff is located at the bottom of the mud drum. One steam outlet and perforated dry pipe is placed centrally at the top of the drum, with provision, on either side, for safety valves.

Union Boiler

THE Union water-tube boiler, as made by the Union Iron Works, of Erie, Pa., consists of 3 main parts, the drums, the headers and the tubes. The drums are arranged in a horizontal position and at the front and rear ends are riveted through special corrugated joints to the headers. The end of each drum is provided with a manhole, and pear-shaped handholes said to eliminate all leakage trouble are cut in the handhole sheet of the headers.

The feed pipe enters the drum near the base of the front head, passes along the bottom of the drum, and delivers the water behind a vertical diaphragm extending from the bottom of the drum to a little above the water line. From there the water passes over the first diaphragm and downward behind a second diaphragm, which extends from the top of the drum to a little below the water line, from where it is delivered into the water space of the rear header. The blowoff connections are

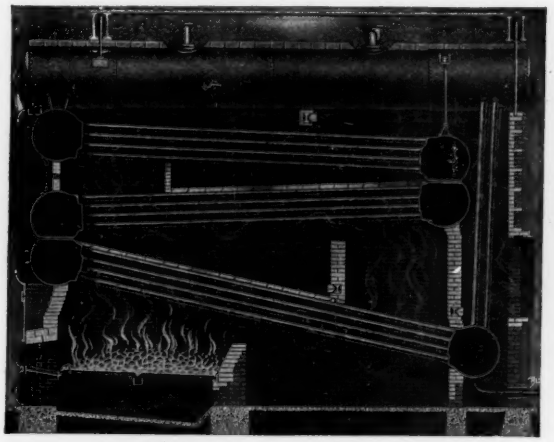
made at the bottom of the rear header; the steam outlet is at the top of the middle third of the drum, while in the front third is a flanged outlet for a safety valve connection.

SECTIONAL VIEW OF UNION BOILER

The front end of this boiler is supported by rods suspended from overhead double channels and hooked into lugs riveted to the side of the drum and, to allow for expansion and contraction, the rear end rests upon rollers and plates, bearing upon a cast-iron standard.

Vogt Water-Tube Boiler

THE HENRY VOGT MACHINE CO., of Louisville, Ky., builds a horizontal water-tube boiler, the upper members consisting of 2 parallel drums suspended from a steel framework by straps at the rear and lugs and hooks at the front. At the front, these 2 drums are connected



SECTIONAL VIEW VOGT WATER-TUBE BOILER

to a similar but smaller transverse drum, into the rear side of which is rolled a bank of tubes connecting in a like manner to a second double transverse drum, the bottom member of which connects by means of a slightly slanting bank of tubes to a second double transverse drum, located below the first. A third bank of tubes connects this and the last single transverse drum, which is located below and to the rear of the first double drum. A nest of straight tubes passes from the bottom of the 2 main drums and enters the top of the last lower transverse drum.

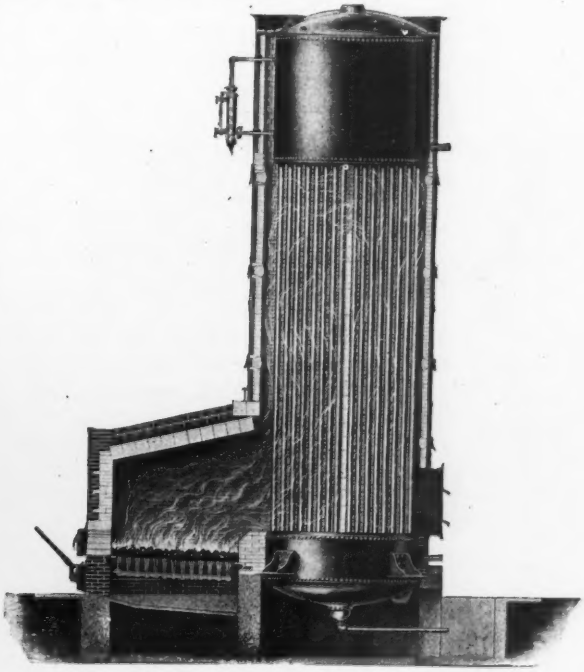
Regular safety valve and steam outlets are flanged to the top of the upper drum while provision is made for a blowoff connection at the bottom of the lower transverse drum. Both heads of the upper drums have manholes but only one head of the transverse member is provided therewith.

Due to the unusual arrangement of tubes used in connection with the transverse headers, a combination of horizontal and vertical baffling is employed.

Wickes Boiler

THIS TYPICAL vertical water-tube boiler consists of a steam and a water drum, one directly above the other, connected by straight tubes, which are expanded and rolled into both tube sheets and are divided into 2 sections by a firebrick baffle, which extends about ¾ the length of the tubes.

The boiler is supported by 4 pressed steel brackets riveted to the shell of the bottom drum, thus avoiding any tensile strain on the tubes.



THE WICKES VERTICAL WATER-TUBE BOILER

As the boiler is entirely enclosed in brickwork, the hot gases not only surround all of the tubes and part of the steam drum, but by means of the vertical baffle are forced to travel twice the entire length of the tubes, resulting in an unusually efficient heating surface. Exposing the steam drum to the products of combustion, also gives superheating surface which tends to dry the steam thoroughly.

In the steam drum, the water line is carried about 30 in. above the tube sheet, leaving a space of 5 ft. between the water line and the top of the drum, affording large disengagement surface. On a level with the

water line and extending over the tubes in the front compartment, is the steam baffle plate to deflect the water of circulation and prevent splashing and spraying water into the steam.

On account of the vertical position of the tubes, neither scale nor soot can adhere to the tubes, but fall to the bottom, where the scale may easily be removed from the lower drum and the soot from the tube sheet. Another worthy feature is that the upper drum is of such height that a man may stand up while operating a cleaner or handling a hose, thus making easy cleaning.

Ordinarily, feed water is introduced into the steam drum below the water line and flows downward through the tubes of the second compartment. The feed water connection may, however, if desired, or conditions so warrant, be made in the bottom drum.

The blowoff is located in the center of the bottom of the lower drum, and the steam outlet in the center of the top of the steam drum with 2 safety valves on either side.

In the convex head of the steam drum are placed one large manhole and a number of handholes, and in the shell of the mud drum another manhole.

All furnaces used with this boiler are of the dutch oven type and may be hand-fired or provided with any one of the stokers now on the market. This boiler is manufactured by The Wickes Boiler Co., of Saginaw, Mich.

Details of Special Boilers

Continental Boiler

THE CONTINENTAL boiler is an internally fired boiler of the Scotch-Marine type and well suited where a large amount of power is desired in a minimum amount of space. Its construction is well shown in the accompanying illustration, from which it may be seen how self-contained this boiler is, requiring no brick setting and the only firebrick used is that which forms the bridge

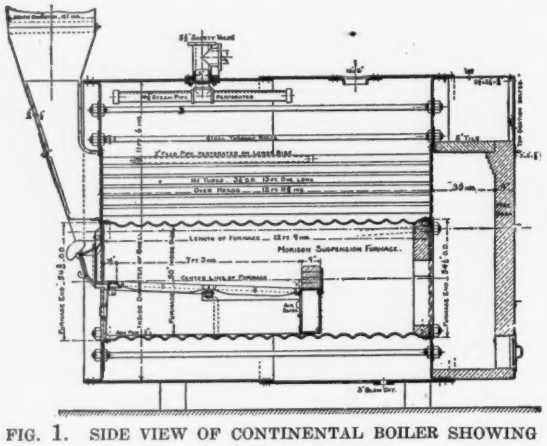


FIG. 1. SIDE VIEW OF CONTINENTAL BOILER SHOWING CORRUGATED FURNACE

wall, baffling and a layer at the back of the combustion chamber. Furnace and tubes are entirely surrounded by water, so that all fire surfaces, excepting the rear of the combustion chamber, are water cooled. To obtain greater strength and to provide a series of joints to take up any strains due to unequal expansion, the furnace is corrugated its entire length. Practically all types of mechanical stokers and grates are applicable to this boiler.

Water enters the shell at about the center, through a 2-in. perforated pipe, while on the upper side are flanges for the steam outlet and safety valve connections. A blowoff is provided in the rear bottom half of the shell.

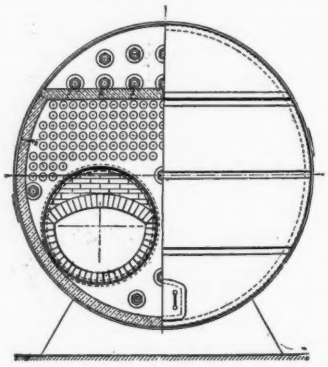


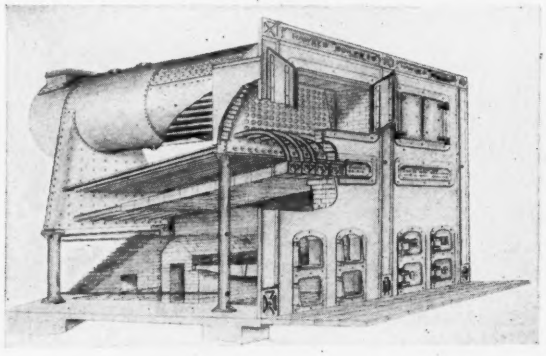
FIG. 2. END VIEW OF CONTINENTAL BOILER SHOWING LOCATION OF FURNACE AND TUBES

The advantages of this type of boiler are minimum radiation losses; no air leakage into furnace; large steaming capacity and absolute safety.

These boilers are not patented, and may be built by any boiler shop having the necessary equipment.

Hawkes Boiler

HAWKES BOILER CO., of Chicago, Ill., build a combination water-tube and tubular boiler consisting of a shell provided with tubes for the passage of hot gases, 2 headers, one at each end of the shell, and 2 rows of tubes lying inclined to the shell. Near the bottom of front header is connected the upper row of water tubes, which slant toward the back and connect to the rear header



HAWKES COMBINATION WATER-TUBE AND TUBULAR BOILER

at about the middle. The lower row of tubes is parallel to the upper row, extends in front of the front header and connects thereto through connection boxes and bent tubes. These tubes are expanded into the bottom of the tube sheet of the rear header.

At each end of each header is a cast-iron column, used as a support, those at the front being rigidly connected while the rear header rests on these columns

through fixed plates and rollers, thus allowing for expansion and contraction.

Arrangement of the firebrick tile baffling and the passage of the gases is well shown in the accompanying figure.

Near the front end of the shell a feed line enters at the side below the water line, and at the highest point in the middle of the shell may be found the steam outlet and perforated dry pipe, with provision for a safety valve directly in front of the steam outlet. The blowoff connection is at the bottom of the rear header.

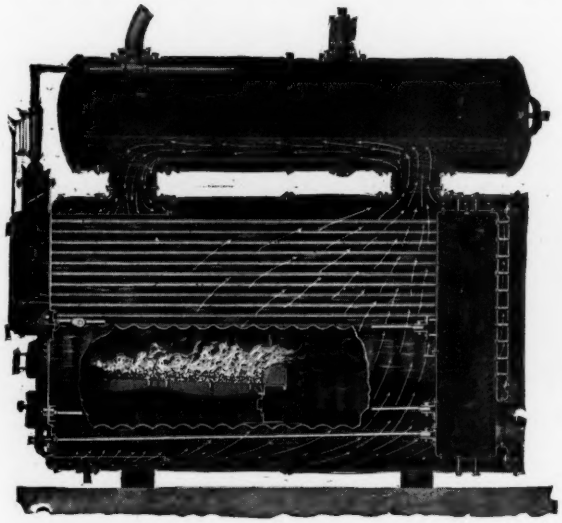
One manhole is located near the top of the rear tube sheet of the drum, while handholes are placed in the rear tube sheet of the header and in each front connection box opposite each tube opening.

Steel or masonry settings are used, as desired, with cleanout doors for the blowing of soot from the heating surface, located where convenient. The flat, inclined roof of the Hawkes furnace insures uniform distribution of the gases of combustion. Heat is carried by the draft away from the boiler front, resulting in a cool front and permitting cleaning tubes with the travel of the gases.

Rapid circulation of the water washes all heating surfaces and removes all scale-forming material, placing them where they can do no harm and where they may readily be blown out. This boiler has large water and large steam space, consequently is capable of responding to sudden changes of load.

Brady Scotch Boilers

A MAIN shell and drum, the former completely filled with tubes above and the internally fired furnaces, form the main parts of this boiler. Around the interior of the shell, below the front neck and having an opening near the bottom, is an annular ring shutting off the passage of the circulating water to front neck, and forcing the



SECTIONAL VIEW OF THE ROBB BRADY SCOTCH BOILER

steam up the rear neck and creating a circulation of water to the bottom of the shell. In the bottom of the upper drum and directly above the opening of the rear neck is a deflecting plate, an additional aid to proper circulation.

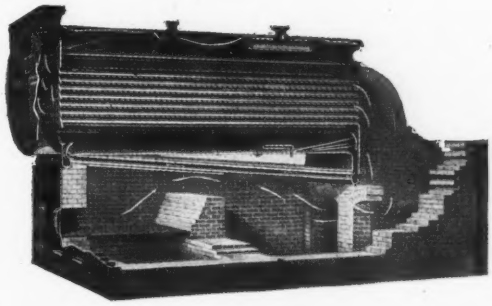
Five manholes, 4 located in the front sheet below the tubes and one in the rear drum head, are provided, together with a number of handholes located around the shell. The steam outlet with dry pipe is located at the front end of the drum, and a safety valve connection at the center thereof, while a flanged blowoff connection is placed near the front at the bottom of the shell.

The foundation of this boiler consists of 2 saddles built up of sheet iron resting on concrete piers.

The International Engineering Works, Ltd., of South Framingham, Mass., and Amherst, N. S., Canada, are the manufacturers of this boiler.

Lyons Boiler

THE LYONS safety boiler consists of a large drum which is in all respects a tubular boiler, but riveted to the bottom thereof, at each end, are 2 short headers having inserted between them one row of slanting tubes. The bottom of the front header is planned so as to allow setting on the top of the boiler front wall, while at the rear end support is by columns at each end of that header. Handhole plates opposite each tube allow ready access for cleaning or repairs.



THE LYONS BOILER

The settings required are comparatively small, as no brick work is necessary above the top of the water tubes, while the drum proper may be covered with asbestos.

This boiler is made in De Pere, Wis., at the Lyons Boiler Works.

Smith Vertical Tubular Boiler

THIS boiler, built in sizes of from 100 to 500 hp. for working pressures of from 125 to 200 lb. gage, is similar to the Manning vertical boiler. Its advantage over this boiler is, however, that the crown sheet can easily be examined and cleaned by means of the space around the tubes large enough for a man to walk in. This space over the crown sheet brings a large body of water into intimate contact with the heat of the furnace, while the upper part of the boiler provides a superheating surface of ample proportions.

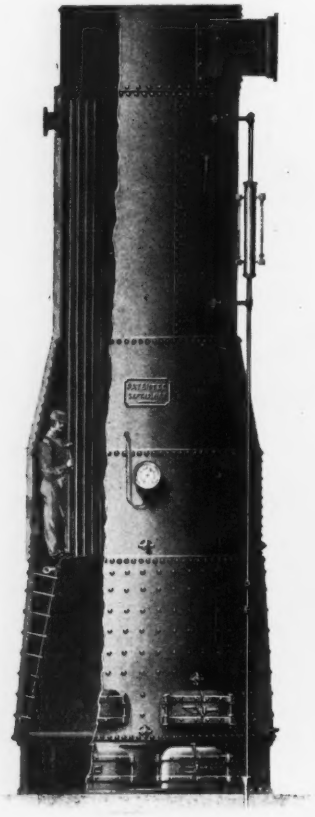
All tubes with beaded over ends are set with gudgeon expanders in drilled and chamfered holes in the tube sheets. The fire box, the height of which can be varied to suit any kind of fuel, is conical in shape, permitting a free circulation of water at this point. For strength and to assist the fall of any mud deposit to the bottom of the boiler, a curved crown sheet is used.

The base, made up of sectional cast-iron rings, to which the fire doors are fitted, is set on a concrete ring, the only foundation required.

Samuel Smith & Son Co., of Paterson, N. J., builds this boiler.

Winslow Boiler

THIS BOILER is of the sectional water-tube type built up of sections each consisting of a vertical front header and a vertical rear header connected by a number of approximately horizontal seamless tubes, the lower ones being inclined toward the rear, the inclination gradually decreasing until the highest tube is practically horizontal. In combining a number of sections or elements into a complete boiler, the rear section header of each is connected at its lower end to a mud pipe, at its upper end to a steam tube, and midway the ends to a feed pipe.

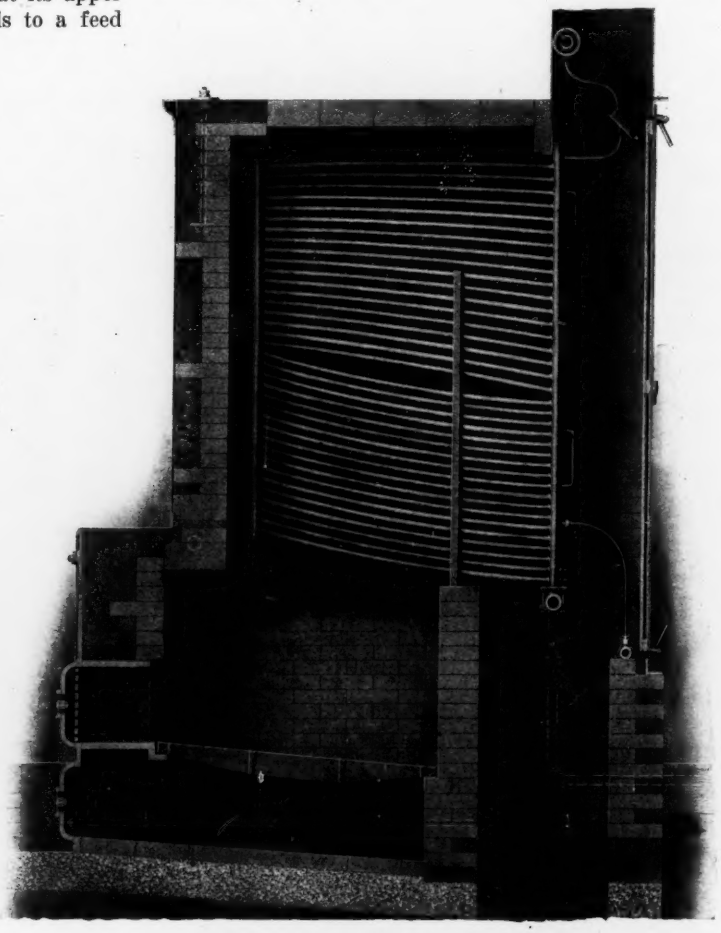


THE SMITH VERTICAL BOILER

From the accompanying illustration, it is readily seen that a part of the furnace gases is carried in front of the section over its top, in order to bring it into contact with the upper, or steam collecting part of the nest of tubes where its heat dries the steam and, if desired, superheats it. The feeding tubes may also be here seen, one belonging to each section, located in the uptake where they act as economizers.

Water drains toward the rear section header through the upper circulation tubes, the steam tending to separate and flow through the front header and the top tubes toward the proper outlet. The returning water does not completely fill the upper tubes of this zone of circulation and evaporation, but it exposes a certain amount of surface from which further separation takes place of such steam as is carried along with the water or as is generated within the return flow tubes.

In boilers carrying pressures and temperatures as high as found in the Winslow, ordinary gage glasses are undesirable. Instead, the water column is a steel tube, surrounded by a steel jacket containing mercury visible in a vertical glass tube. Due to that part of the mercury which surrounds steam in the column absorbing much more heat than the part surrounding water, the average temperature of the mercury and consequently its height in the glass tube is an indication of the water level,



WINSLOW SECTIONAL WATER-TUBE BOILER

being high for low water and low for high water.

This boiler is controlled by the Winslow Boiler Co., of Chicago, Ill.

ANALYSIS OF samples of coal to determine accuracy of the common method of sampling show agreement of the average of separate analysis of each sample, and single analysis of an average sample obtained by continued selection, mixing and quartering, within 3 per cent.

Boiler Operation

Hand Firing of Furnaces

IN HAND FIRING of furnaces there is a combination of science and art which can usually be acquired only after years of experience in the boiler room. To be most successful, the fireman must keep in mind that the furnace is a chemical retort in which reactions take place, and that to get the desired results, definite proportions of fuel and air must be used and the proper distribution of air made.

While the object of the furnace is to create heat, the greatest amount of heat can be obtained only when the proper chemical reactions take place; hence the fireman must know what these are, in what part of the furnace they take place, and when proper conditions are established. He must also know how to rectify the variations from the requirements, first determining what these variations are, either by the aid of instruments or from judgment based on previous experience. The chemicals with which he works are the fuel and the air which are supplied to the furnace. These he must so handle as not to get an over or under supply of either, and that the air will be introduced in the proper places. He must also be able to recognize defects in the condition of his fuel bed, such as the existence of holes, clinkers, too thick or too thin a fire. Art in handling a furnace consists of the skill with which the fireman is able to handle his tools and to judge the condition of his fire by the color which it has. For convenience in firing, stationary grates should be on a level with the bottom of the fire door, to allow of using the slice bar and other tools to best advantage.

Tools and Methods

We will consider, briefly, the tools which should be provided for the fireman who is to handle bituminous coal. First, the shovel should be of proper size for the individual who is to do the work. This depends upon his height, strength and skill in delivering the coal to the proper part of the furnace. It is of great importance to have the shovel of the proper shape and that it be kept always in the best condition with straight end, for a worn shovel is often the cause of coal being spilled into the ashpit, or thrown where it is not desired upon the fuel bed, besides being an aggravation to the workman whose efficiency is impaired.

A form of rake used in many power plants is shown in the illustration, its purpose being to scrape the ashes from underneath the bed of coal and push them through the grate into the ashpit. It is also used as a clinker hook to remove clinkers from the furnace. This form of rake has, as will be noted, but 2 prongs, the ends of which are flat, which prevents the prongs from becoming fast in the openings of the grate. The hoe, which is to remove all coals and ashes clean from the grate, has 2 forms, one being a winging tool which pushes the coal from one side of the furnace to the other when cleaning is being done. In some plants the form of T bar shown in the illustration is used for working the ashes through the grate bars without lifting the bed of coals from the grate. All three of these tools, rake, hoe, and T bar, are provided with long, light handles, making

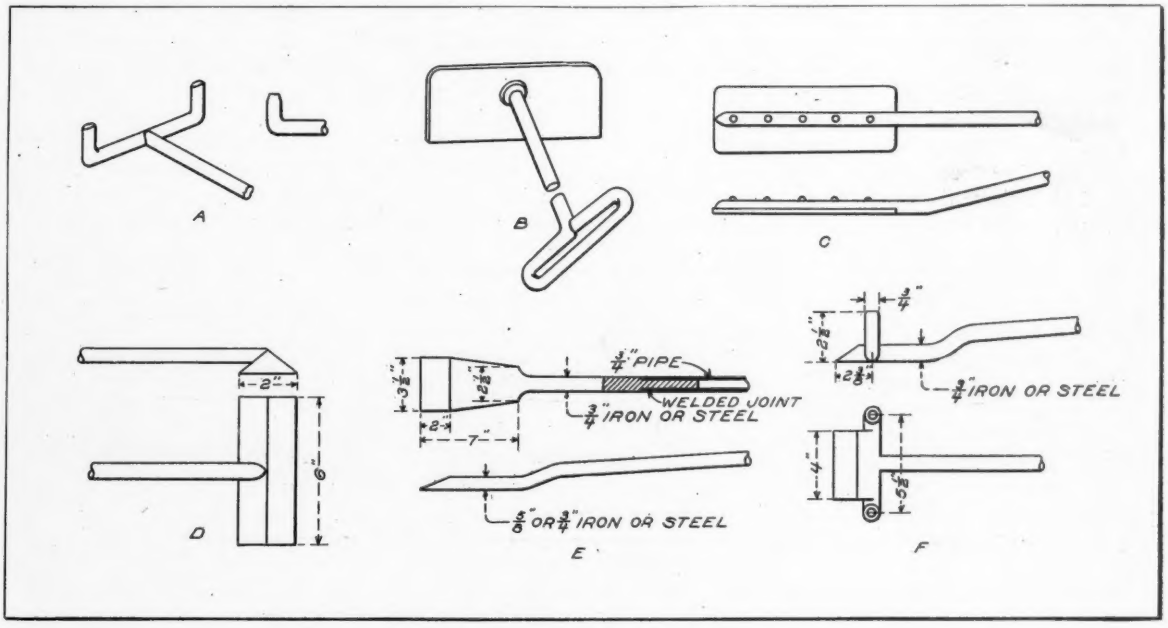


FIG. 1. FIREMAN'S TOOLS. A, RAKE; B, HOE; C, PARALLEL HOE; D, SPECIAL T BAR; E, SLICE BAR; F, COMBINATION RAKE AND SLICE BAR

them easy to use, and, the lightness inclining the fireman to use them more frequently than otherwise.

The slice bar is the fireman's chisel, which to do good work with least time and labor, must be of the most advantageous form and shape. Its work is not to break up clinkers by continued thrusts into the fire, but to raise the bed of clinkers clear of the grate so that they can be removed by the clinker hook. The larger the pieces of clinker removed at one time the better, because the grates can thus be freed of these troublesome obstructions in a shorter time, so that less cold air will enter the

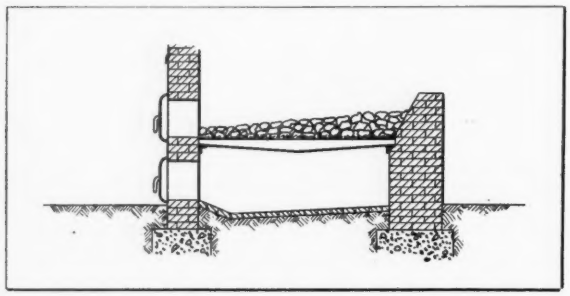


FIG. 2. FUEL BED IN WEDGE SYSTEM

furnace. In order to loosen a large area of clinker with a single thrust of the slice bar, the bar must be of proper shape and sharp, so that it will slide along the grate bars instead of riding up on the first bed of clinker it reaches. A dull slice bar must be moved back and forth a number of times in order to accomplish what might be done with a single thrust of a sharp bar.

Conditions determine the form of angle at which the handle to firing tools should be bent. For the grate situated high above the boiler room floor a certain shape and a particular angle will be needed, and when the grates are relatively lower another form and angle will prove the most effective. The beveled edge on the slice bar should be wide enough and deep enough to avoid breaking the cake of clinker so that the latter may be removed as quickly as possible.

Methods of Firing

When bituminous coal is to be fired by hand, the lumps should be broken to the size of a man's fist, and the coal should be delivered on the boiler room floor close enough to the firing door so that the fireman does not need to take more than one step between the furnace and the coal supply, or, preferably, in industrial cars with drop side or end and bottom at height of fire door, as this convenience will save labor and considerable loss of heat due to the furnace door being left open longer than it should be.

Several systems have been devised for firing bituminous coal, the selection depending largely upon the individual doing the firing and the construction of the furnace. Probably the most common system is the spreading of the coal over the entire surface of the grate in a thin, even layer. This is, without question, the easiest and simplest method where the furnace is provided with but one firing door, and may be used with good success where the furnace is equipped with a dutch oven or ignition arch which holds the heat and reflects it upon the green coal, driving out and igniting the volatile gases rapidly soon after the charging is done. The disadvantage of this method is that without proper provision of ignition arch considerable smoke is likely to be formed, particularly, if the charge of coal is heavier than it should be.

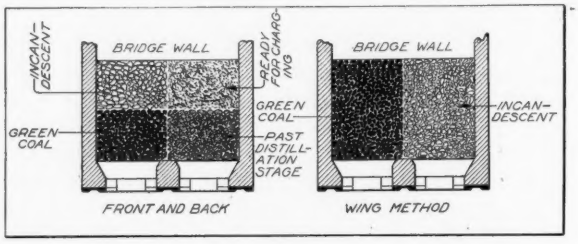


FIG. 3. ALTERNATE SYSTEMS OF FIRING

To overcome one of the great difficulties of the spread system of firing, in some plants the bed of fuel is kept in the shape of a wedge with the thick part near the bridge wall, thus preventing the coal at the back of the furnace from burning out quicker than at the front, thus forming rat holes in the furnace. Otherwise this system is the same as the spreading method.

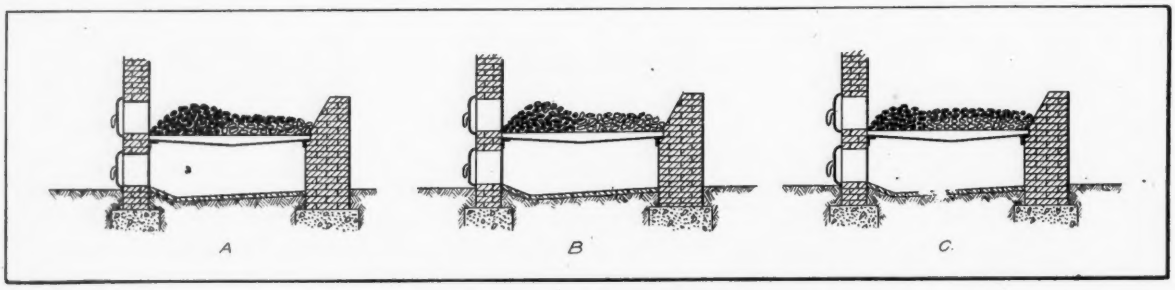


FIG. 4. STEPS IN COKING SYSTEM

During the past decade considerable study has been given to methods of firing which will do away with smoke, particularly in cities where ordinances forbid plants from issuing black smoke into the atmosphere. One of the most popular methods of firing to abate smoke is known as the alternate system, which may be alternate charging of the front and back, or the wing. In the front and back method that section of the grate which is charged through one firing door is divided into 2 parts, which are replenished alternately, spreading the

coal evenly over each section of the grate, and allowing it to ignite thoroughly before the other section of the grate has coal thrown upon it. For example, if a furnace has 2 firing doors, the fireman would throw coal upon the back of the first section, then upon the front of the second section, following this when the coal in the back of the first section has partly burned by shoveling upon the front of the first section, then upon the back of the second section.

In the wing system, which is adaptable to furnaces having 2 or more doors, the entire section of the grate accessible from one door is charged at the time. When this section has become fairly ignited the second section is charged and the process repeated as frequently as the load upon the boiler demands. By either of these methods volatile gases given off by the green coal are ignited and burned in the furnace which is kept at a high temperature by the coal on the section which is not being charged.

Another non-smoking system, particularly adapted to internally fired boilers, is coking, which consists essentially in charging green coal at the front only, and when the volatile gases have been driven out and burned, the remaining coke is pushed to the rear over the incandescent coals and more green coal is thrown on the front of the furnace.

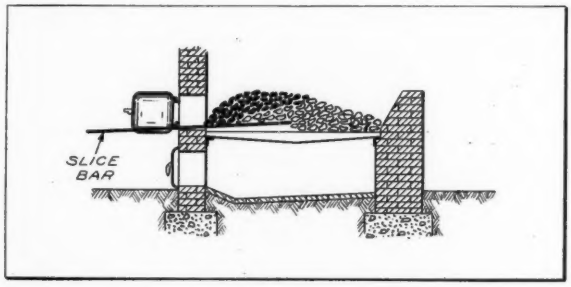


FIG. 5. PROPER METHOD OF SLICING

To start a fire in a furnace where the coking system is to be employed, cover the grate with well broken coal to an average thickness of about 4 in., and then put about 5 scoops of live coals on top at the bridge wall; close the fire door, and leave the damper open. Fire will then burn from the back to the front with much less smoke than by any other method, as the gases distilled from the fresh coal will pass over the hot fire bed and be ignited.

When fire has covered the entire grate, push the fuel bed toward the rear, and fill the front of the grate with fresh coal from 8 to 12 in. deep, which should be left undisturbed until nearly all coked; meantime the front door should be cracked and heavy draft used. When the coal is coked, shove it back and repeat the operation as often as necessary.

In all but the coking system the thin charge of green coal should be spread upon the surface of the coal while the fire is in an incandescent state, and before it has changed color. The firing should be done as often as the condition of the load requires, but the charge should always be the same amount and the fireman should work quickly while the door is open. After the coal has been spread upon the fire it should not be disturbed unless it is found that a hole has developed through the fuel. In this case the hole may be covered by a shovelful of coal.

Cleaning Fires

Bituminous coal from a great many mines is likely to form clinkers, giving considerable trouble to the fireman, particularly at times of peak load. When this occurs it may be necessary to bar the fire, but this should consist only of a slight raising of the bed of fuel, and not passing the bar up through it, as the clinkers will mix with the fuel, causing not only smoke, but a reduction of the temperature of the furnace and the fusing together of the live coals with the clinkers. After the clinker has been raised from the grate it is removed as quickly as possible with a clinker hook or rake, without disturbing the fuel bed more than is necessary.

Cleaning the fires should be done while the load upon the plant is at the low point, the frequency depending upon the load being carried on the boilers and the kind of coal used, varying in different plants from every 3 hr. to once a day. Cleaning should be done as quickly as possible, and to avoid smoke, only one boiler of a battery should be cleaned at a time when possible. Broken coal should be thrown on the wings of the furnace on each side for a distance of 3 or 4 ft., and allowed to coke for a time with the front door cracked open and the draft turned on. When the last charge of coal is burning well, close the ashpit door and rake out all the old fuel from the central portion of the grate. Fill the cleared space with well broken coal to a thickness of 4 or 5 in. and let this green coal get well coked from the live beds at the side.

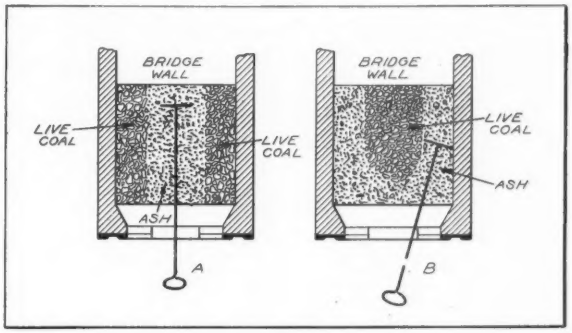


FIG. 6. CLEANING STATIONARY GRATE

If it is necessary to raise the steam more quickly, the burning fuel on the sides can be winged over the top of the green coal and after this, or the previous operation, the ashpit door should be opened and the full draft turned on the furnace. When the middle portion of the fire is well ignited, rake out the sides which will be nearly burned out, then charge with fresh, broken coal and allow this to burn without winging over and with the fire door cracked open and the draft on. Fires need cleaning when black spots or shadows are seen in the ashpit which cannot be removed by barring the fire.

To bank the fire, it should first be cleaned, then pile the unburned fuel up at the bridge wall, cover it with green fuel, close the damper to such a point that it will

remove the accumulation of gas without creating a draft, open the fire door and close the ashpit door. The amount of green coal to be used depends upon the length of time the fire is to be banked.

To start from banked fires, clean the fire by removing the ashes, spread the fuel, open the draft doors and dampers and close the furnace door.

Firing of shaking and dumping grates is the same as that of the stationary grate, with the exception that by shaking the grate bars, the accumulation of ash and small clinkers may be cut from beneath the live coals, while with the stationary grate it is necessary to use a T bar or rake. The dumping feature of shaking grates facilitates the cleaning process, in that the coals do not have to be hoed out of the furnace but can be dropped through the grate.

Dumping grates are usually divided into 2 sections, front and back, for each firing door, allowing each section to be cleaned separately, the process being to rake the unburned coal from the section to be cleaned, dump the ashes into the pit as quickly as possible and then shove live coal upon the bare grate and cover with

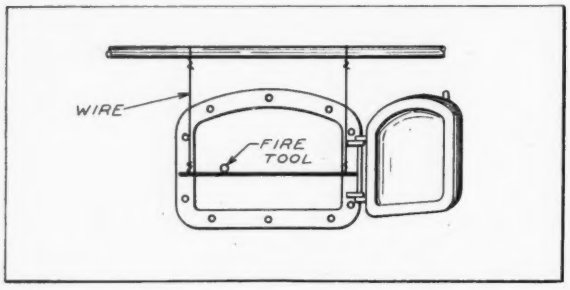


FIG. 7. SUPPORT FOR FIRE TOOLS

green coal. When the cleaned section is burning at or near incandescence, the other section is cleaned in the same manner.

Anthracite Firing

Handling an anthracite fire is entirely different from the work with bituminous coal, largely because anthracite coal does not coke and has but a small percentage of volatile constituents. The spreading system is employed quite frequently with good results, but the alternate wing method is more popular. In nearly all plants where anthracite is burned, it is necessary to use forced draft, and in this case after the fires have been charged small holes will be seen to develop in the fuel bed, which should be covered by means of a light leveling bar or hoe. Anthracite coal does not as a rule give difficulty from clinkers, but of late years washed coal has been used in some plants, and this does give some trouble. The method of handling and removing clinkers is the same as with bituminous coal, but the use of a T bar to remove the ashes is not necessary. Shaking grates are not needed with anthracite coal. In some plants a rod is swung across the front of the furnace door upon which the handle of the leveling bar slides, making it easy to run the bar over the surface of the fuel without disturbing the bed.

To avoid the heat and glare of the furnace being thrown upon the face and eyes, some firemen throw on a shovelful or 2 of coal next the door, which allows the fireman a view of the back part of the furnace.

In closing, it may be repeated that, to get best results, the fireman must keep in mind the fact that combustion is a chemical process, and such conditions should be maintained as to give the right proportions of air and fuel and the proper temperature and time to complete the union of oxygen and combustible elements.

Stoker Firing

COMBUSTION of fuel is a process which, when properly carried out, takes place with mathematical exactness, and such precision can hardly be expected when furnaces are fired by hand. The coal being first heated, drives off the volatile matter, compounds of carbon and hydrogen, which, when ignited and properly supplied with air, combines with the oxygen to form carbon dioxide, CO_2, and water, H_2O. The residue upon the grate is coke, containing the fixed carbon of the coal and the ash. The coke being heated and supplied with the proper amount of air burns off the carbon to form CO_2. It will be seen by this that the fuel goes through definite stages in the process of combustion, and the object of mechanical stokers and furnaces is to carry these processes on at the proper speed, supplying the proper amount of air for complete combustion and arranging the grate so that the greatest amount of heat will reach the heating surfaces of the boiler.

The advantages of mechanical stoking, aside from the labor saving, lie in the uniformity with which the combustion takes place and the prevention of air rushing into the furnace when the coal is being fed.

It will be realized that with a process so exacting as that of burning coal, there are many difficulties to be overcome, due to the different kinds of coal which are available, and types of boilers. These difficulties have given rise to several different types of stokers which may be classified into the traveling chain grate, the front and side feed gravity, underfeed, gravity underfeed and sprinkling stokers.

Traveling Chain Grate

This type of stoker has been designed principally for use in burning bituminous coal of the Central States, and consists essentially of an endless chain, the links of which form the grate bars of the furnace, and carry the coal from the hopper in front to the bridge wall at the rear. The hopper extends the full width of the furnace, being supplied by coal either from a chute or by hand from the floor, and is fitted with a gate which is usually lined with fire brick, and may be raised or lowered, according to the depth of fuel it is desired to carry on the grates. For several feet over the front of the grate extends an ignition arch which reflects the heat of the furnace upon the green fuel to distil off the volatile combustible of the coal and furnish the heat necessary for the ignition of the gas. The process of combustion is carried out through the distillation of the gases to the burning of the carbon, and the ashes are dumped over the rear end of the grate to

the ashpit. The grate is usually driven by a ratchet wheel and dog, operated from an eccentric on a shaft either above the furnace or below the boiler-room floor, the driving mechanism being provided with some means for increasing or decreasing the speed of the grate.

With a uniform load upon the boiler, the various stages of combustion are carried out in definite parts of the furnace, and the furnace may be operated continuously with no more attention than is necessary to keep the machinery in working condition. There are 2 methods of adjusting the furnace to take care of varying load, one being to change the speed of the chain, which may usually be done by shifting a shield over the ratchet wheel, allowing the dog to engage more or less of the cogs in the wheel as it works back and forth. The proper rate at which the grate should travel depends upon the rapidity with which the coal burns, but may be considered correct when the fuel at the end of the grate has completely burned, but there should be no ash space at the end of the grate through which air may enter the furnace.

The second method of adjusting for load is by means of the depth of the fuel upon the grate which is regulated by the gate opening from the hopper. The depth of fuel which should be carried depends upon the load being carried, the grade of coal and the available draft. The depth should be such that no holes will develop in the fire through which an excess of air will come into the combustion chamber, yet it should be thin enough so that sufficient air will come through the fuel bed to furnish the oxygen needed for complete combustion.

Coal used should be crushed to such a size that uniform feed will be obtained. Coal from the size of a man's fist down to that which will go through a half-inch screen can be used to good advantage, though even slack or screenings can be burned with fair results.

One of the difficulties which has been encountered with the chain grate stoker is to secure the proper distillation of the volatile gases and their ignition in the front part of the furnace so that the combustion of the coal may be complete at the end of the grate. To overcome this difficulty it is necessary to build the ignition arch at such an angle that the heat of the furnace will be reflected upon the green coal, and the angle is different for coals having different proportions of volatile matter. The length of the arch also has a great deal to do with the proper ignition of the coal, and should be such that all volatile matter has been driven from the fuel before it passes beyond the arch.

Caking coals, which are quite common in the Central States, are frequently used upon this type of grate, and during the process of distillation form a cake which prevents air from passing through the bed as it should to insure complete combustion. To overcome this difficulty, some chain grates are run upon rollers in such a way as to give the furnace of the grate a wavy motion sufficient to break up the cake and provide spaces through the bed for the air necessary for combustion; in another type, a distinct drop of several inches is made in the surface of the grate for this purpose.

With some classes of coal, clinkers will attach themselves to the side walls of the furnace, extending part way over the grate. This difficulty is overcome in some plants by placing a dead plate beside the grate which will accumulate ashes and prevent the clinker from adhering to the walls. Another scheme is to allow a small air space between the furnace wall and the grate which will cause any clinker which may form to crystallize without attaching to the walls of the furnace. A perforated steam pipe along the edge of the grate, blowing a small amount of steam into the furnace, will soften up any clinker which may attach to the walls of the furnace, or it is quite feasible to place a water pipe on the sides of the grate to prevent the adhering of clinker to the furnace walls.

When clinkers form upon the grate, there is little that can be done to remove them; but, as the grate turns over the sprocket wheels at the rear, the clinkers are

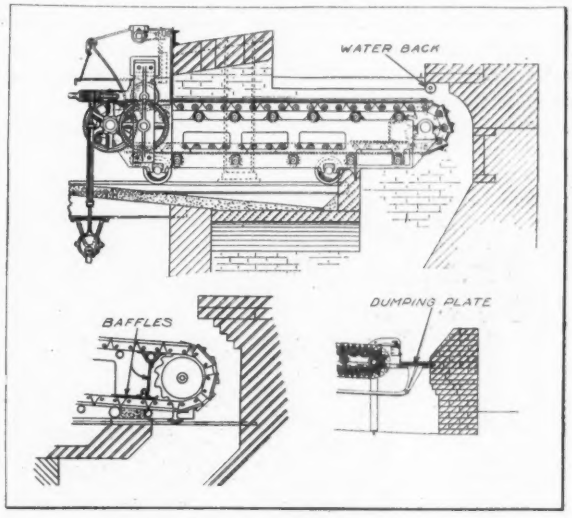


FIG. 1. CHAIN GRATE STOKER

broken from the grate bars and drop into the ashpit. A method employed by some to prevent clinkers from forming is to wet the coal thoroughly in the hopper before it is fed into the grate, and to keep them soft a jet of steam under the grate is sometimes used.

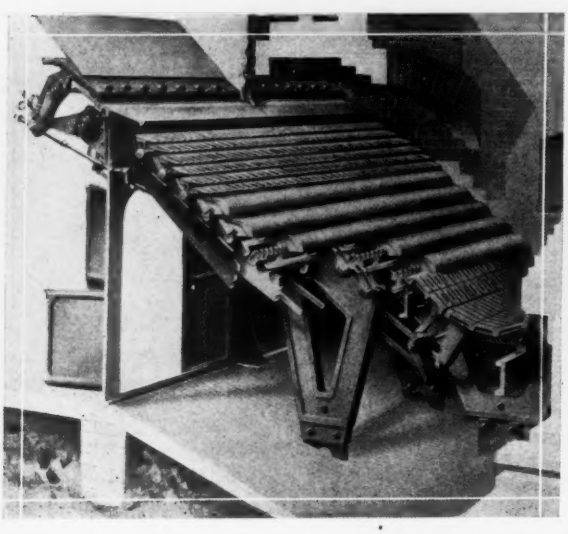
With fine coal, such as slack or screenings, difficulty is sometimes encountered with coal dropping through the grate before it is burned, or dust being carried up into the gas passages. In such cases the ashpit is usually of such construction that the coal drops into a pan and may be shoveled back into the hopper, or falls into a hopper beneath the grate, which discharges into a coal conveyor, this in turn delivering it to the coal bunker and again to the furnace. Wetting the coal thoroughly in the hopper before it is fed to the grate also prevents sifting down of the fine particles until they become caked together.

One of the most prevalent causes for loss in the operation of chain grates is the leakage of air past the grate in front of the bridge wall. To prevent such a loss, the fuel should be burning until it reaches the end of the grate, or within a few inches from it, and, with the fire extending so far back, clinkers may form upon the bridge wall and clog up the furnace. To prevent such a difficulty, one of the most common methods of construction is to provide a water back which extends over the rear of the grate and forms the edge of the bridge

wall. Cold water passing through this part serves to cool the molten clinker and prevent it from adhering to the brick of the bridge wall; the water thus heated is afterwards delivered to the boiler so that no heat is wasted by this device.

In other types of grates, baffles or dump plates are provided at the rear, the baffles preventing the air from entering beyond the grate, and the dump plates catching the clinker, allowing the coke, which is intermixed, to burn out before being dumped into the ashpit.

In the maintenance of chain grate stokers, the links which form the grate sometimes burn out and break, causing the fuel to leak through unduly, and give trouble as they pass over the sprocket wheels at the front and rear of the grate. Sometimes coal clogs in the hopper and leaves bare spaces upon the grate surface, which not only cuts down the rate of combustion, but allows air to enter and cool the furnace gases below the normal operating temperature. This difficulty may be overcome by placing an agitating device in the stoker hopper near the gate, consisting of a bar with projecting pins extending the length of the hopper.



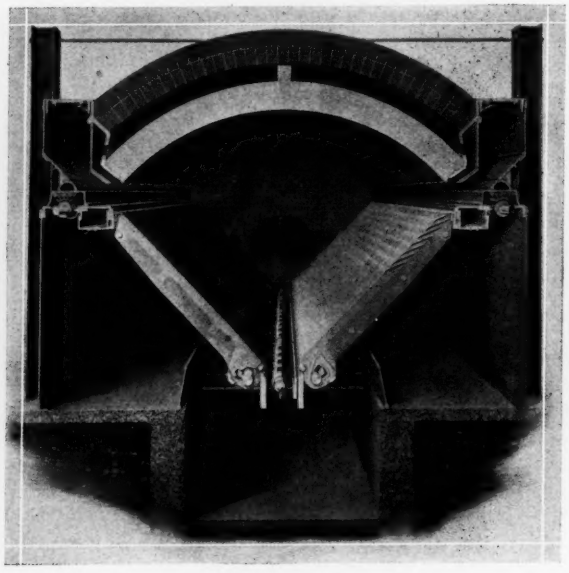


FIG. 2. TYPICAL FRONT AND SIDE FEED GRAVITY STOKERS

When it is desired to bank the fire in one of these furnaces, the proper method is to shut off the draft and run the grate at its slowest speed, the depth of fuel being regulated according to the length of time the fire is to be banked. To put out the fire the feed gate should be run down to its lowest point, and the grate allowed to travel until all the burning fuel has been consumed or run over the back of the grate into the ashpit.

Whenever the boiler is down for cleaning or repairs it is advisable to go over the stoker and examine it for defects such as burned links, worn bearings, leaky water backs, cracked dump plates or broken baffles. This precaution may prevent the shutting down of the boiler during a peak load when it is most needed.

Gravity Stokers

These are constructed with their grates on an incline, down which the coal, being fed at the top, slides slowly, assisted by the working of the grate bars. When the furnace is in operation, gases are distilled from the coal as it first enters the furnace and lies at the top of the grate. This stage of combustion is aided by an ignition arch which reflects the heat of the furnace upon the green coal, and as it is worked gradually down the incline it is coked, fixed carbon is burned, and the ash discharges on a dump plate or clinker crusher at the bottom of the incline.

In one kind of gravity stoker, grate bars extend across the incline, causing a step-by-step process of the coal, the motion of the bars being to dump the burning coal from one bar to the next until it is discharged into the ash receptacle. This type of stoker is designed principally for anthracite coal which moves readily from one grate bar to the next.

The other type of bars extend lengthwise of the incline, being notched on the surface to prevent the coal from sliding too rapidly to the ash receptacle, and the air supply comes through horizontal grooves on the sides of the grate bars.

One of the principal points in the construction of either of these types of stokers is to have the incline of the grate proper for the kind of fuel which is being used. Otherwise, considerable difficulty may be had in getting the coal to slide down the incline, or it may go too rapidly and cause air holes to develop in the fuel bed. In fact, the operation of the furnace consists principally in covering the holes which develop on the grate bars with fuel, and prying the clinkers loose from the grate. For keeping the grate covered, some sort of bar of sufficient length to reach the back of the furnace may be inserted through a small door beside or in front of the stoker hopper, or the grate bars may be shaken in such a way as to cause the coal which has accumulated above a hole to drop into its proper place. To remove clinkers, a slice bar is convenient for grates which extend lengthwise of the incline. When the bars extend across the grate the proper tool to employ is a bar with a thin blade at the end which may be inserted between the grate bars from beneath.

Of the 2 types of gravity stokers, one, called the front feed, has the coal hopper extending across the front of the boiler with the grate inclining downward toward the rear. The other type is the side feed with a coal hopper on each side of the furnace and the grates inclining toward the center forming a V-shaped furnace. With the front feed type the condition of the fire can be readily seen from beneath the grate surface, and the coal worked to cover holes from doors, one on each side of the coal hopper in the front of the furnace. With the side-feed type of furnace the fire must be watched from a door in the front of the furnace, which is of sufficient size to allow for the insertion of fire tools to keep the fuel bed in proper condition.

As with the chain grate stoker, some difficulty is encountered with unburned fuel passing through the grate, when it first enters the furnace, or due to the working of the grate bars. This coal is caught in a pan and shoveled back into the hopper; wetting the coal in the hopper will prevent this to a considerable degree. Here again the same trouble with the coal not feeding regularly from the hopper to the grate may be experienced, and under such conditions the installation of an agitator may be advisable.

Underfeed Stokers

These are especially adapted for burning bituminous coal, for the reason that the volatile gases must pass up through the incandescent bed of coal, thus becoming thoroughly heated and igniting before passing to the heating surface of the boiler. With a thick bed of coal through which these gases must pass, it is necessary, in most cases, that forced draft be used to carry on combustion properly.

In one type of underfeed stoker the coal is fed into a horizontal retort by means of a plunger or screw conveyor and the bottom of the retort is so inclined as to cause the fuel to rise at a uniform rate the full length of the retort. As the coal gradually rises through the fuel bed it is heated and the volatile matter driven off through the incandescent coal at the top, air under pressure being furnished through holes on the sides of the retort. As the fuel rises, it overflows to grates on either side of the main body of fuel, where combustion is completed and from which the ashes and clinker are removed.

Attendance of this class of stoker consists principally in keeping the machinery moving and regulating the air supply. In cleaning, the fire is allowed to run down as low as load conditions will permit, and when the coals on the side grates are well burned out, clinkers may be loosened from the grate by the use of a slice bar and taken from the furnace with a hook or rake. After the clinkers have been taken out, green coal is thrown upon the grate to cover the surface. With some kinds of coal, clinkers may form over the main bed of coals and the fire must be watched and these clinkers removed with a clinker hook, so as not to disturb the main fuel bed, in order that proper combustion may take place.

With this class of stoker, fires may be banked by stopping the air blast and pumping in a good supply of green coal, keeping the damper closed and the furnace door open. Before banking, however, the fire should be cleaned so that on breaking up the bank the fire may be put into operation quickly and the best conditions immediately secured. To put out the fire, shut off the draft, clean the side grates by either dumping or raking the coals out, wing the remaining fire from the center to the sides and dump or rake out upon the floor in front of the furnace, quenching the fire with water as it is being pulled out.

Another type of underfeed stoker depends upon gravity to keep the surface of the bed clear of ash and clinker. In this case the fuel bed rests on an incline and is supported at the bottom by an extension grate. The coal is supplied to a hopper underneath which are placed 2 plungers in each retort, one beneath the other, which work alternately and push the fuel up from beneath into the retort, where, as the fuel gradually rises to the surface, the gases are first distilled off, passing through the incandescent coals at the surface and the carbon burned out of the coke as it reaches the surface of the fuel bed, the ashes rolling to the dump plates at the bottom of the incline. Air is admitted through tuyeres at the sides of the retorts under a pressure varying from 1 to 5 in. of water.

To build up a fire on this type of furnace, the furnace should be clean, then pump into the retorts about 2 hopperfuls of coal upon which, through the front door, pile wood, and light with oily waste. Allow the wood to burn with the damper and front doors open until well started, then start the forced draft, close the furnace door and put the furnace stokers into operation. Starting fires in this type of furnace is very rapid, in fact, it may be carried on so quickly as to be injurious to the boiler and settings.

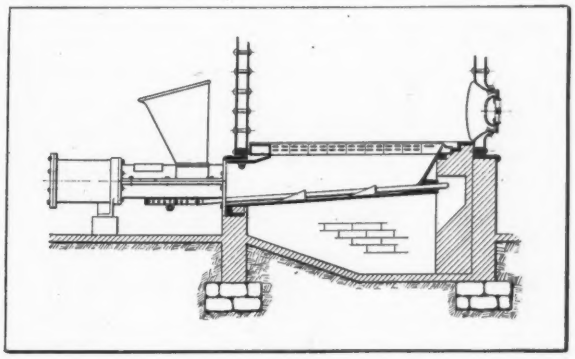


FIG. 3. HORIZONTAL UNDERFEED STOKER

After proper adjustment has been made, there is little to be done in the operation of the stoker except to watch the draft and stoker engines. Of course, such difficulties as the coal becoming clogged in the hopper may occur when wet coal is used, but this difficulty may be remedied by means of an agitator as previously explained.

As explained above, these stokers have 2 plungers for each retort, one above the other; the upper plunger taking the coal directly from the hopper, has a long stroke and delivers part of its charge to the furnace while a certain portion goes to feed the lower plunger whose operation alternates with the upper. To secure the proper distribution of the coal in the furnace, it is necessary that the relative length of stroke of the 2

plungers be carefully adjusted for the kind of coal which is being used. A careful study of the operation of the furnace will soon determine whether the lower plunger should have a greater or less travel, for when too great, unburned coal will be pushed off onto the extension grate leaving the tuyeres at the upper part of the retort with less coal upon them than those at the lower part.

One point requiring care in the operation of these stokers is to secure the proper draft and stoker feed regulation. While it is customary in many plants to operate the stoker and fan by the same engine, to secure the proper relation is a problem, for with too great an air pressure the tuyeres become bare, and with insufficient pressure, coke will be pushed over onto the dump plate. In some plants, best results have been secured by providing separate engines for the fan and the stoker. The fan engine is regulated according to the steam pressure, that is, a falling off of the steam pressure in the boiler will cause an increase in the speed of the fan engine, and vice-versa. The speed of the stoker engine is controlled by the pressure in the wind box of the tuyeres. When the air pressure increases, which is a call for a higher rate of combustion, the stoker engine is speeded up accordingly. With the proper adjustment on the governing mechanism for the stoker engine this scheme works almost entirely automatically, taking care of all fluctuations in load which may come upon the boiler.

Some grades of coal give considerable trouble with clinkers which adhere to the sides of the furnace, and even arch over the entire fire if the stoker is not large. Ashes carried up from the bed of the fuel have, in some

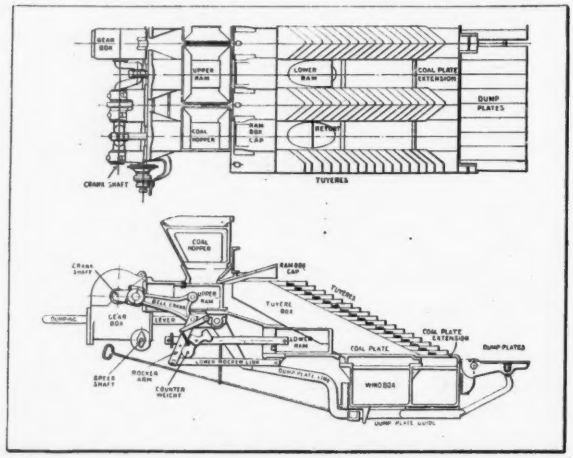


FIG. 4. GRAVITY UNDERFEED STOKER

cases, lodged on the side of the furnace, causing the molten mass to run down the sides of the furnace onto the adjoining tuyeres. To overcome both these difficulties, space is sometimes left between the stoker and the sides of the furnace through which air may pass and cause the molten clinker to crystallize before it reaches the stoker tuyeres. Another scheme is to place a perforated steam pipe in the setting, or even a water back which serves the same purpose.

To remove the clinker from the sides of the furnace, a long steel bar with a chisel point may be used, driven with a heavy sledge. If the clinker is soft, an ordinary slice bar will serve the purpose. In either case this method is detrimental to the lining of the furnace, and if possible, clinkers should be prevented from adhering to the brick.

To clean the fires, a slice bar may be used for breaking up the clinkers in the furnace, and by means of a hoe these can be pushed to the dump plate where they are allowed to remain until the coke which they have collected is burned out, when the contents of the dump plate is discharged into the ashpit where it is cooled by means of water.

When it is desired to bank a boiler, the fire should first be cleaned thoroughly, then the air shut off and the damper closed. A good supply of coal should then be pushed into the furnace so that the burning coal will fall to the extension grate; then the clutch to the stoker should be opened and the fire remain untouched until the boiler is wanted for use. If, however, the boiler remains banked for more than one day, more fuel should be pushed into the furnace to safeguard the tuyeres from getting overheated and warped.

In case of an accident to a boiler which requires that the fire be put out quickly, the method employed by some engineers is to open the dump plate, shut off the air blast and with the damper remaining open, turn water on fire and push it into the ashpit where it may be quenched with water. Under ordinary operation, the above method could hardly be recommended, as it is inadvisable to pour water into the furnace while it is hot. In this case, cut off the coal supply, and when the fire has become thin, cut off the air supply and run the plunger as long as it works the coal, then rake the coals into the ashpit and quench with water.

Sprinkling Stokers

Taking the place of the man-operated shovel, sprinkling stokers throw the coal over the fuel bed continuously or at short intervals, similar to the alternate system of hand firing. The advantage of these stokers is that they save considerable labor in the handling of coal, and the fire door is kept shut except at times when the fire is being cleaned. Coal fired is, of course, mechanically exact in amount and the coal is spread evenly in the different parts of the furnace. These devices are usually placed in the fire door of furnaces similar to those which are hand fired, and the method of taking care of the fuel bed and grate is precisely the same as in hand firing.

Fuel Bed

To the experienced fireman, there is no better indication of the state of combustion of fuel than the appearance of the fuel bed, and with the aid of a draft gage there is little chance for mistake in determining what are the shortcomings of the fire.

When too little air is being supplied to the fuel, which may be caused by too thick a bed of coal, an accumulation of ash on the grate or low draft in the furnace, the bed of coals has a peculiar color, somewhat darker than incandescence, which is the desirable heat. Under such circumstances the furnace is almost certain to give off considerable smoke and the gases will show a percentage of CO. When the fuel bed is too thick, a draft gage connected to the furnace at such a time will

read high in comparison to what it should when the furnace is properly operated.

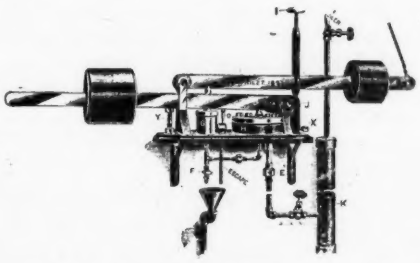
On the other hand, when more air than is needed for proper combustion is passing through the fuel bed, it is more than likely that the live coals over the grate are too thin and holes soon develop through the fuel, giving to the surface of the fuel bed the appearance of a number of gas torches with dark centers and peculiar ring of incandescence around the holes in the fuel. At such a time the draft gage would show a low reading and the flue gases would have a low percentage of CO_2.

Clinkers are likely to occur in the burning of any coal which is available for power plant use, and their presence in a fuel bed is indicated by an inactive spot, which is likely to be somewhat darker than the rest of the fuel bed. Another indication of clinkers is shadows in the ashpit; when the fire is in proper condition there should be an even glow all over the ashpit, and in the furnace an even, clear, white heat with a fully covered grate. The temperature which exists in the furnace is roughly determined by the color of the fuel bed as follows: Faint red indicates a temperature of about 960 deg. F.; bright red, 1300; faint cherry, 1500; bright cherry, 1600; dull orange, 2000; bright orange, 2200; white heat, 2400; dazzling white, 2700 and over.

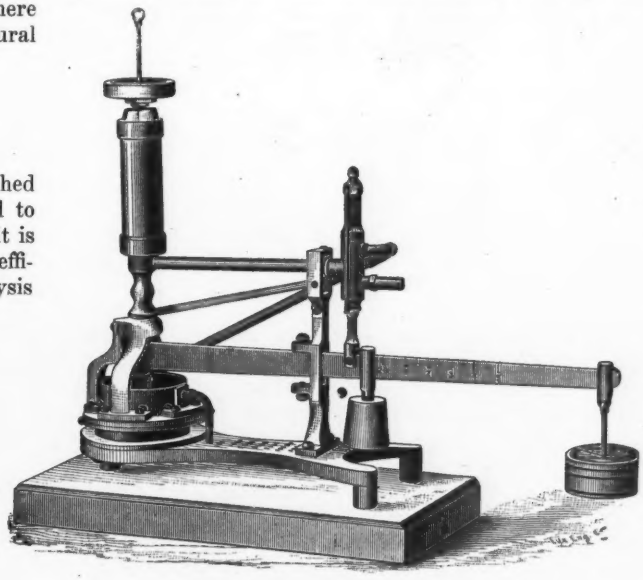
The proper depth of fuel which should be carried over a grate depends upon the grade of coal, available draft and the load upon the boiler. Good results may be secured from anthracite buckwheat coal even under forced draft with a fuel bed 4 in. thick, and the proper thickness runs up as high as 15 in. in cases where bituminous run-of-mine coal is used with good natural draft.

Draft Regulation

IN handling boiler furnaces, success can be reached only when the proper amount of air is supplied to the fuel, so as to reach every particle of fuel as it is being burned. Too much air is as detrimental to efficiency as too little; in the former case, gas analysis would likely show low CO_2, high oxygen and no CO; with too little air, even if properly distributed, the gases would show a percentage of CO, indicating incomplete combustion. The amount of air theoretically required per pound of coal is quite readily calculated; but practice has proved that best results are secured when an excess of 50 to 100 per cent of air is used, the difference depending largely upon the type of grate and furnace.



LOCKE HYDRAULIC DAMPER REGULATOR



BURROWS DAMPER REGULATOR

Until recent years, the handling of draft was an art learned only through long experience; today, however, instruments are available to show the draft in various parts of the setting, also immediate effects on capacity and perfection of combustion due to changes in draft conditions. The handling of draft is, therefore, reduced to a science and in a few days of observation and experimenting, the proper thickness of fire and amount of draft for different loads can be ascertained.

Natural draft created by a chimney is the most commonly employed today, and for proper results should be in excess of all requirements of the plant. This may be supplemented by induced draft created by a fan, or forced draft delivering air under pressure to the under side of the grates. In any case, it is necessary to control the amount of air passing through the grate to suit the load conditions of the boiler.

Where natural draft is depended upon, it is customary in the most modern plants to install an automatic damper regulator in the breeching just before it enters the stack. This damper should be so constructed or adjusted that it will never close completely, or difficulty with escaping gases is likely to be encountered when, due to a sudden falling off of load, the boiler pressure goes up before the fires can be checked.

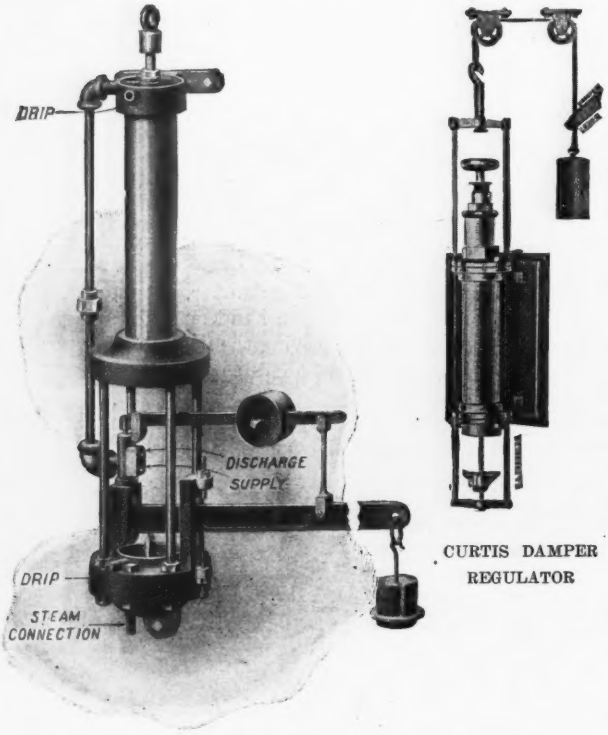
Supplementing the automatic damper, the most common arrangement is to employ a hand operated damper in the uptake of each boiler, giving the fireman an opportunity to handle individual boilers as may seem best to meet conditions.

Another arrangement for controlling the draft automatically, which is used in some plants, is to operate the dampers on the individual boilers from a shaft running the length of the boiler room and controlled in position by a regulating device which varies with the steam pressure. A convenient means of disengaging any damper from the shaft is provided so that any boiler may be operated independently of the damper regulator.

Induced draft is used in cases where the friction losses through the boiler setting and economizer are so great that a chimney of the necessary size is impractical. The induced draft fan is usually installed in the breech-

ing between the economizer and the stack, the speed of the fan engine being regulated to increase when the steam pressure goes down and decrease when the steam pressure rises. The fan engine takes the place of a damper regulator used with natural draft.

While the proper method of controlling the draft is by means of the dampers, there are times when judicious handling of the ash and fire doors produces the desired results. Under operating conditions, the ash door should, as a rule, be kept wide open and the fire door shut tight; when a fire is banked, however, the reverse should be the case.



FORD DAMPER REGULATOR

CURTIS DAMPER REGULATOR

At times, after firing with bituminous coal, the volatile gases are driven off the coal faster than air can be drawn through the bed of coal to cause complete combustion, and in such cases, air admitted over the coal through the fire door has a beneficial result, provided judgment is used as to the time and amount the door or vent is open. This method is used in some devices known as smoke preventers, timing devices being attached to the front of the boiler to close the opening after a definite period, and in some cases a steam jet is used to mix the gases.

Combustion is aided and economy increased in some plants by supplying the furnace with heated air. The method of heating varies with the construction and type of furnace, but the idea is to take the air through ducts in various parts of the furnace walls or boiler settings so located as to prevent the heat from radiating to the boiler room. This practice not only results in better economy but in some cases the deterioration of parts of the setting is reduced considerably.

When boilers are forced considerably above their rating, or where the resistance of the fuel bed to air is considerable, as when fine coal is used, or it is necessary to carry a thick fuel bed, forced draft is often used. In this case, with ordinary furnace construction, the ash-pit is closed with air-tight gates and doors and an air pressure ranging from 1 to 5 in. of water, depending upon conditions, is maintained under the grates.

In some plants, the air pressure is produced by a fan which discharges into a duct with branches to the several boilers; in others, individual fans are installed in the boiler setting; still another method is to install a steam jet which not only furnishes air under pressure, but a certain amount of steam which, it is claimed, is beneficial in softening clinkers which may form on the grates. In any case, the pressure carried under the grates is automatically maintained proportional to the load carried and the speed of the fan or the valve opening to the steam jet is controlled by the steam pressure in the boiler, the lower the steam pressure the higher the air pressure developed, and vice versa. Where one fan supplies several furnaces, means are provided whereby the air to any one furnace can be controlled by hand or automatically, thus giving flexibility in the operation of the plant.

Within the last few years, what is known as the balanced draft system of combustion control has come into quite common use. The object of this system is to maintain the pressure over the grates as nearly that of the atmosphere as possible and to reduce the speed of the gases over the heating surface to the minimum allowable for the load being carried.

A damper regulator whose action depends entirely upon the direct steam connection from the boiler is made by the Burrows Manufacturing Co.

In this case, steam enters a small condenser, from which the condensation passes to the under side of a diaphragm, the pressure upon which is counterbalanced by a lever and weight.

The movement of the diaphragm operates a pilot valve, directly under its center, which controls the flow of the condensation to a water cylinder containing a piston which in turn operates a lever that is connected to the damper by a chain and which in turn is counterbalanced by weight on this arm. Adjustment is made from one point, screw marked x.

The Curtis improved damper regulator, made by Julian d'Este Co., consists of a gun-metal bronze cylinder, within which is a long, loose-fitting plunger fitted with water grooves, making it both tight and frictionless.

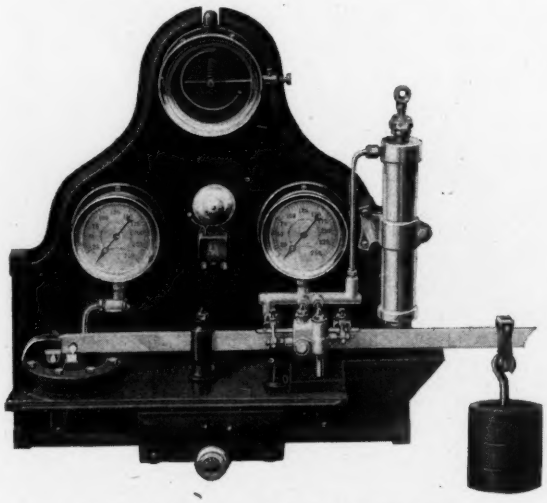
The motion of the plunger is communicated by a yoke and chain to the lever of the damper, on which is hung sufficient weight only to open the damper and overhaul the plunger. The plunger is operated by steam direct from the boiler, and the whole pressure in the boiler is therefore available, if needed, to operate the damper. As a matter of fact, only so much pressure is used as is requisite to lift the weight, usually not more than 10 lb. to the inch on the plunger. The admission of steam is controlled by a sensitive metallic diaphragm, which operates the valve.

To operate it, a given load is produced on the diaphragm by screwing the handle in. When the pressure in the boiler reaches the limit, it lifts this load, and permits steam to enter the space over the plunger, slow-

ly pushing it down and closing the damper. When the boiler pressure falls below the limit the valve closes, and the pressure passing from the bottom to the top of the piston, puts the piston in equilibrium and allows the weight, slowly settling down, to open the damper, thus controlling the pressure at the desired limit.

The Ford damper regulator is operated by steam pressure acting on the under side of a diaphragm the movement of which is transmitted through a weighted lever to the auxiliary valve which controls the flow of water to the hydraulic piston that moves the valve.

In the improved Locke hydraulic damper regulator, steam at boiler pressure is admitted beneath a diaphragm, this pressure being counterbalanced by a weighted lever, the position of which changes with fluctuations in steam pressure. A pilot valve attached to the lever controls the water to and from the water motor which operates the damper, and cutoff attachment prevents the full stroke of the damper.



THE MC DONOUGH DAMPER REGULATOR

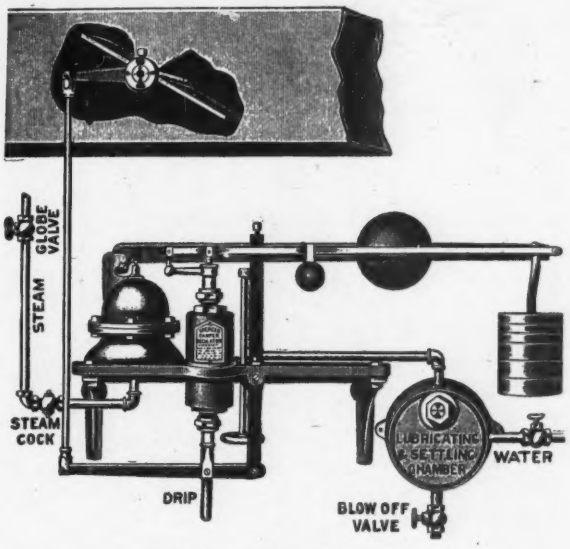
An arrangement consisting of a damper regulator, stoker engine or motor speed controller, with steam pressure gage, water pressure gage, a signal lamp showing the open position of the dampers and a low steam pressure alarm bell, all mounted upon one board, making a convenient unit, is manufactured by the McDonough Automatic Regulator Co.

Operation of the regulator depends upon the pressure of steam under a diaphragm. Any variation in boiler pressure causes the movement of a weighted lever and this controls a pilot valve admitting water to the motor, which operates the damper through a chain. The speed governing mechanism for the stoker drive is attached to the same chain so that simultaneously with the opening and closing of the dampers the speed of the stokers will increase or decrease, supplying the proper amount of coal to the furnaces for the immediate load on the boiler.

In the operation of the Mason Hydraulic damper regulator, steam pressure from the boiler acting under the diaphragm balances the weighted lever which, in turn, operates the pilot valve controlling the admission and exhaust of water pressure to the cylinder. When the steam pressure in the boiler falls below the required amount, the lever will fall, moving the valve rod and pilot valve. This permits the water on the under side of the piston to flow off through the drop pipe and at the

MASON HYDRAULIC DAMPER REGULATOR

same time admits water to the top of the piston, causing it to move downward and open the damper. It is obvious that if this were the only mechanism, the damper would be either entirely open or completely closed at each change of steam pressure in the boiler.

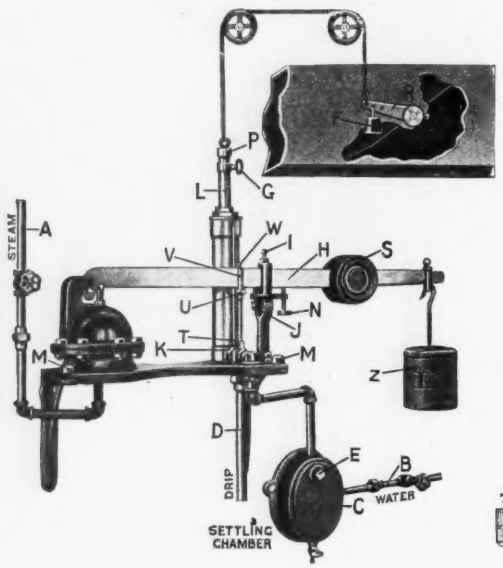


SPENCER DAMPER REGULATOR

A compensating arrangement is therefore provided which, by the action of the cam in contact with a sliding wedge operates the compensating mechanism and readjusts the pilot valve so as to cause the regulator to come to rest until another slight change in boiler pressure occurs, when the operation will be repeated. This action

takes place within a variation of less than 1 lb. in the boiler pressure. When the boiler pressure rises, the valve rod is forced up by the action of the weighted lever opening the pilot valve and by the admission of water to the lower end of the cylinder the piston is moved upward, closing the damper. The upward movement of the piston actuates the compensating wedge so that the cam in contact with it closes the pilot valve and prevents the piston from making a complete stroke. Either chain or rod connections may be used to connect the regulator with the flue damper. When chain connections are used, a counterweight is hung on the flue damper lever to provide the power necessary to operate it in one direction.

A positive and graduated movement in both directions is secured by the Spencer damper regulator, made by the Spencer Regulator Co. This permits, in most cases, connecting the lever on the damper to the regulator lever by a rod or stiff connection. The damper is under the direct control of a motor operated by water pressure, and will be held in any position so long as the desired pressure is obtained in the boiler. Steam pressure acts under a diaphragm the movement of which is transmitted through a series of weighted levers to the controlling valve of the water motor. A variation in pressure of 1 lb. will cause the damper to swing full stroke; any less variation from that desired will cause the damper to remain in an intermediate position which will give proper draft to restore the desired pressure.

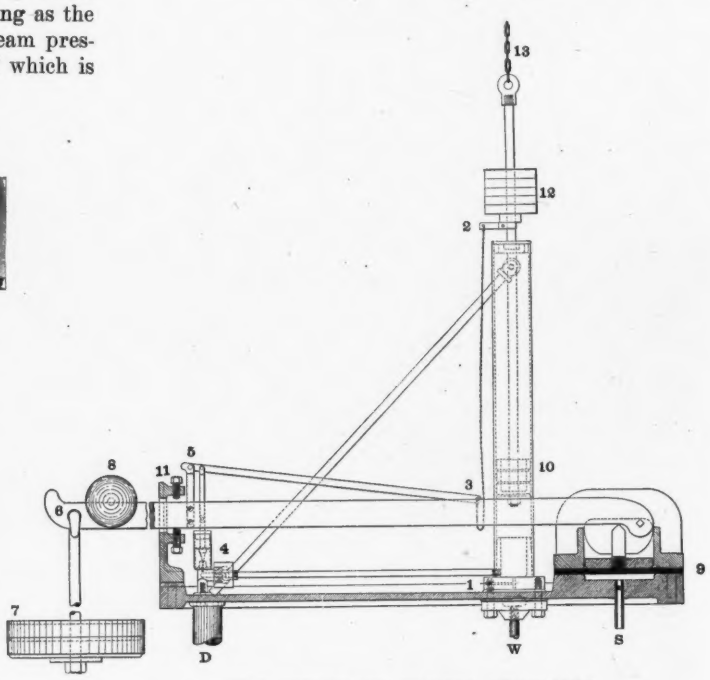


LAWRENCE DAMPER REGULATOR

Control of the position of the damper is by means of a double-acting water piston with the Lawrence damper regulator, made by Watts Regulator Co. Steam pressure acts on the under side of a diaphragm and is counterbalanced by a weighted lever which in turn is attached to the pilot valve controlling the flow of water to the cylinder. Water passes through a settling chamber, which allows sediment to settle out and for lubricating purposes soap is placed in a cage beneath the plug.

The "Wydawake" damper regulator, made by L. J. Wing Mfg. Co., consists of but 3 parts: The diaphragm upon which the steam pressure acts, the piston and cylinder which operates the damper or blower valve, and the relief valve. There are 2 sets of weights, one for rough adjustment and one for fine adjustment. An 80-mesh screen, easily removable, is placed where the water enters the regulator so as to keep the water clean.

When the steam pressure is up, the piston will be in its lowest position. If the pressure now decreases slightly on the diaphragm, it allows the lever bar to drop, which lowers the point 5 of the lever, thus closing the relief valve and causing the water pressure to force the piston up, and thus open the damper. As the piston approaches the end of its stroke, it pulls the chain taut, thus lifting the point 3 of the lever, opening the relief valve very slightly, and decreasing the pressure on the piston. This will cause the piston to remain in its position until the steam pressure has reached the desired point for which the regulator is adjusted. When this pressure has been reached, the pressure on the diaphragm is, of course, increased accordingly and the bar rises, lifting the point 5, thus opening the valve and releasing the water pressure. The piston thereupon descends, due to the weight on it, and closes the damper, or blower valve.



THE WYDAWAKE DAMPER REGULATOR

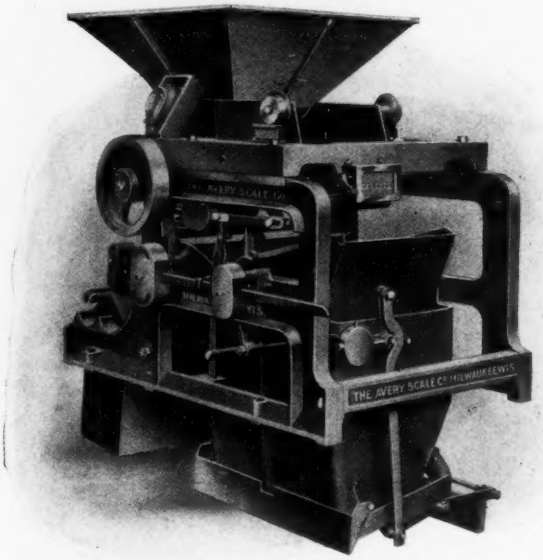
The pressure at which it is desired that the damper close is fixed by adjustment of the weights and which balance the pressure against the diaphragm.

It is easy to cut down draft if too much has been provided; but if the draft is feeble, power cannot be produced when emergency demands, and great care is necessary to prevent making smoke.

Coal Measurement at the Plant

IN THE operation of a power plant, there are several reasons why coal should be weighed as it is fed to the furnace: it allows a comparison from day to day of the power output and coal consumption; by this means the value of different deliveries of coal can be compared; the ability of the men in different shifts can be compared; a bonus system can be used in paying firemen, which has worked to mutual advantage in many plants; it frequently points out losses which creep in unnoticed unless daily comparisons are made.

The most convenient means for weighing coal delivered in railway cars is a set of scales which weighs the whole car, and this method is quite universally employed. Deliveries made in barges are usually weighed before loading by the coal company, and this weight is checked at the plant. The coal delivered to storage is thus made a matter of record.



AVERY AUTOMATIC BITUMINOUS COAL SCALE

Coal taken from storage to bunkers is usually weighed in industrial cars or the weight carefully estimated. When no further means of weighing are employed, it is customary to graduate the bunkers and each week or month estimate the amount of coal remaining in the bunkers. A better plan, however, and one employed in many of the most efficient plants of the country is to install automatic scales in the chute from the bunker to the stoker hopper, or one set of scales in the form of a hopper traveling on an overhead track may be used to weigh the coal to all boilers facing one aisle; the latter arrangement has the advantage that only one set of scales is used and coal from one end of the bunkers can be used in any furnace; the disadvantages are that it requires a man to operate it and to make a separate item in the records of the coal to each furnace causes some inconvenience.

In the absence of a more accurate method, where certain types of stokers are used, it is a good plan to determine the amount of coal fed at each stroke and put a stroke counter on the stoker; a fairly close estimate can be made by this means and is decidedly better than nothing.

In hand fired plants, coal may be weighed in wagons as it is delivered to the floor from the coal company's yard, or when brought from the storage to the firing floor in wheelbarrows or industrial cars, platform or floor scales to good advantage. Here again close estimates can be made by using the average weight of the load carried.

Coal delivered through chutes to the floor from a bunker overhead can be estimated, in the absence of convenient scales, by having 2 coal valves in the chute, one at the bottom, the other at the top; the chute is alternately completely filled and emptied and a record is kept of the number of times the valves are opened.

THE HAVARD COAL METER

Knowing the average weight of the contents of the chute, an estimate of the amount used during any shift is easily made. This method is also employed in some plants where stokers are fed from overhead bunkers.

The Avery automatic coal scale is a weighing machine built on the even-balance principle, with hopper at one end, and weight-box at the other. For anthracite coal, the feed through a top hopper, is controlled by a curved gate, the full stream being automatically brought to a dribble to finish off the weighing. The weight of the coal bringing the beam to a balance causes the striking of a pin which opens the hopper door, and allows the coal to discharge, at the same time completely closing the supply gate. A counter-balance closing the hopper door after discharge, automatically re-opens the supply gate and immediately another weighing is begun.

An entirely enclosed counter mechanically connected to the supply gate, registers "one" at each weighing so that a reliable and continuous record of the coal passing through the scale is automatically obtainable. A compensating beam is arranged to allow for the amount

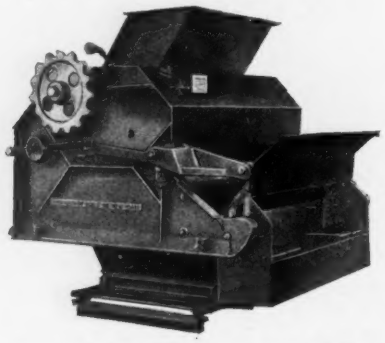
of coal in suspension after the gate closes, this compensator being set but once, for a particular coal used, and continuing thereafter to insure accurate weighings without further attention.

For bituminous coal, the supply gate is replaced by a mechanical agitator operating automatically with the discharge door of the hopper. Its angle being the angle of repose of the coal, there is no feed until the tray begins to agitate; from then on the feed is uniform until the agitator is automatically stopped by the beam coming to a balance and the discharge gate opening. This agitator is a mechanical device, positive in action, driven through a bellcrank and shaft and thrown in by a mechanical clutch. It requires but a small amount of power to drive, which may be derived from separate small motor furnished extra with the scale upon request, or from convenient line shaft. In other respects this scale is fitted exactly similar to the anthracite coal scale.

The Havard coal meter consists of a spiral rotating vane or "measuring ribbon"; a recording meter with visible dial; and a frame containing shafts and gears connecting the spiral rotating vane with the recording meter.

The spiral rotating vane is suspended in the center of the pipe or coal chute by the supporting frame. The discharge of this pipe must be so controlled as always to maintain a solid body of material to be measured while passing the meter. As the coal passes downward, the spiral rotating vane is revolved in direct proportion to the amount of drop, which is proportional to the weight of coal withdrawn. The rotation of the vane is transmitted by means of suitable shafts and gears to the counter operating the visible dial.

Illustrated herewith is the type of Richardson automatic scale commonly installed in power plants for weighing coal. It has numerous applications, such as weighing coal into storage, from storage to bunker, but chiefly from bunker to boiler for providing an efficiency check.



RICHARDSON AUTOMATIC COAL SCALE

It takes up but little space and can be installed under a hopper or on a traveling carriage to run on rails the length of the boiler room.

The scales are entirely automatic and may be adjusted to discharge any quantity of coal at each load within in the capacity of the scale. Each discharge is automatically recorded, so that it is only necessary to take the register reading at such intervals as may be desired. These scales are the product of the Richardson Scale Co.

Measurement of Feed Water

ONE of the most important records kept in the power plant is that of the water fed to the boilers, for this record, together with coal consumption gives the performance of the furnace and boiler more definitely than any other means available during practical operation. Owing to the fact that in most plants the water must be measured while it is hot there has been, up to the last few years, no really accurate means for recording the weight of feed water. When the water is pumped directly from the city mains to the boiler, or through a closed system of heating without the addition of returns, the readings of the city water meter serve to give the desired record. This condition, however, does not prevail in most plants, so other means must be resorted to.

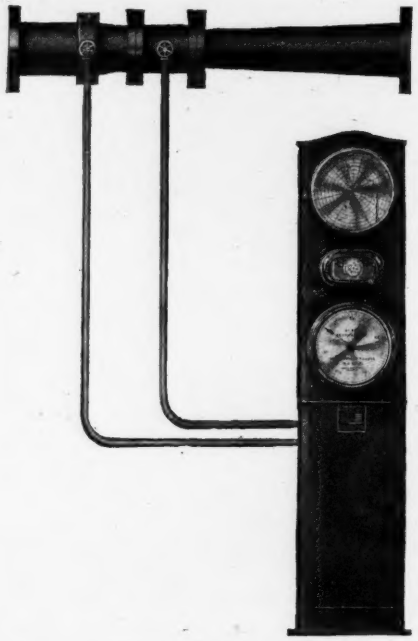


FIG. 1. REGISTER-INDICATOR-RECORDER VENTURI METER

An instrument known as a Venturi meter, made by the Builders Iron Foundry, depends upon the fact that when water flows through a pipe containing a contraction, the pressure at the throat is less than at the inlet or beginning of the contraction. This difference of pressure can be accurately measured by a U tube containing mercury, and it is found to increase approximately as the square of the throat velocity. The instrument proper is connected to the meter tube by means of 2 small pipes and provided with mechanism which records and integrates the water which has passed through the tube. The resister or recorder may be placed in any desired location.

There are no parts to become warped by high temperatures, so the meter can be used to measure hot feed water. The meters are graduated for a temperature of 62 deg., but a curve is furnished with the instrument which makes corrections for temperature easy.

Another class of meters which has come into popular use in the past few years is of the weir type. These are

particularly adapted for use with feed water heaters as the combination makes a compact unit, the readings of which are sufficiently accurate for practical operation.

The Hoppes V-Notch meter, manufactured by the Hoppes Manufacturing Co., consists of a tank to which a cabinet is attached. On the inside of the cabinet is a vessel suspended by a coil spring connected to the tank by a flexible metal hose. As the water flows over the V-notch it rises in the vessel inside the cabinet, which contains just enough water at each unit in height to draw down the spring in exact ratio to the rate of flow. This permits the recorder and integrator to be directly attached to it without the use of cams, or other motion changing devices.

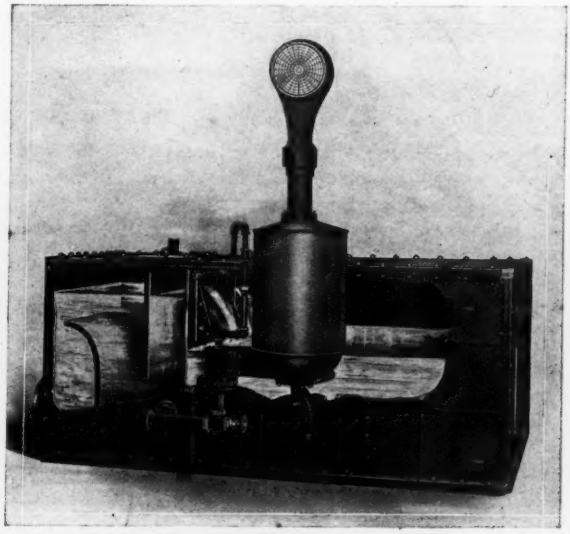


FIG. 2. HOPPES V-NOTCH METER

The recording and integrating apparatus is located in the head on a column supported by the cabinet. A clock movement in the head operates a 24-hr. circular chart on one side and on the other, an aluminum disk making one revolution per hour. A vertical guide with a crosshead running between anti-friction bearings is located just below the head and is connected to the vessel. The pen for making the record on the chart is attached to the crosshead on one side, and an arm supporting a small planimeter wheel on a vertical axis is carried to the other side. The planimeter wheel, which is revolved by the aluminum disk, moves a train of gears operating the integrator, and rests at the center of the disk when the water is at the lowest level of the V-notch. As the head increases and the weighing vessel descends, the planimeter wheel is drawn toward the lower periphery of the disk, and as this wheel operates the integrator, the amount of water passed is indicated, while the rate of flow is recorded on the chart.

These meters have been very successful in their operation, and can be used independently, or in connection with the Hoppes feed water heaters.

In the Cochrane metering heater, made by the Harrison Safety Boiler Works, the settling chamber of the heater is utilized as the still water chamber for the V-notch weir, and a float in the outflow or discharge chamber of the meter controls the cold water inlet by admitting water to the heater. The V-notch weir is easily checked by the user independently of the indications of the registering and recording instrument by reading the head of water acting on the weir and using the formula for calculating the flow.

In a special float chamber communicating with a quiet part of the settling chamber above the V-noteh, called the float chamber, is a large float properly balanced so that it will hold the stem perfectly upright without other support. The upper end of the float stem is connected by means of a micrometer screw adjustment to a double cable wound about a drum attached to a revolving cam by means of which the movement of the float and the movement of the pen carriage are correlated in such a way that equal increments in the rate of flow cause equal displacements of the pen.

FIG. 3. COCHRANE V-NOTCH RECORDER

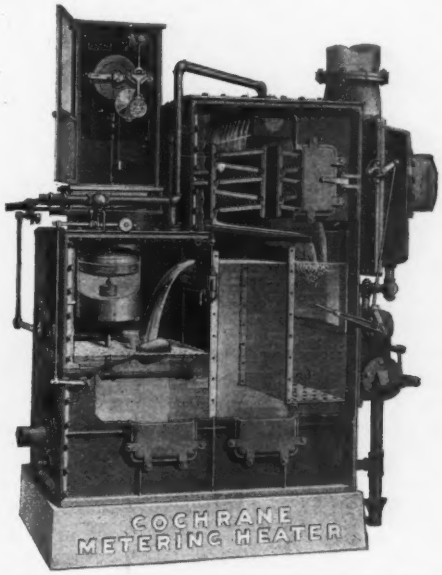


FIG. 4. APPLICATION OF COCHRANE METER TO HEATER

The use of a cable and drum avoids back-lash and irregularity of motion, also has the advantage that by varying the size of the drum it is possible to obtain any desired relation between the maximum float travel and the maximum head travel, thus making it feasible to use one cam for all heads and all rates of flow. The reversed movement of the cam is secured by means of a counter balance from another cable which maintains the float stem under constant and uniform tension. The cam itself is cut as a spiral slot in a flat disk which makes 2½ revolutions for the total pen travel.

The cam follower is attached to the pen carriage which travels by means of rollers upon a horizontal track. The pen is held against the paper upon the clock drum by gravity, and the entire pen and holder

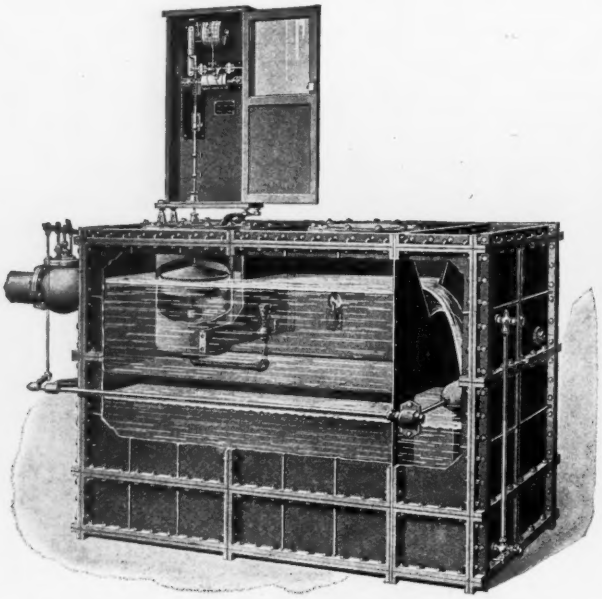


FIG. 5. LEA V-NOTCH RECORDING LIQUID METER

can be lifted off the carriage for filling or cleaning without loosening screws or other connections. The integrator is suspended from the pen carriage in such a manner that it may be lifted off. The integrating roller of the counting train rests against the flat aluminum disk driven by a clock.

The metering heater can be supplied in all the special adaptations of the Cochrane heater and Cochrane hot process of water softening systems.

The Lea "V" notch recording liquid meter, manufactured by the Yarnall-Waring Co., Philadelphia, consists essentially of a metering tank upon which is mounted an indicating and recording mechanism. The metering tank is divided into suitable compartments, near the top of one of the partitions is a "V" notch of known angle through which the water flows into a storage compartment, from here it is drawn to boiler feed pump or for other purposes.

Riding on the surface of the water flowing over the "V" notch is a float in a protected chamber. From the float a rod passes vertically through bottom of instrument case to a rack and pinion revolving a metal drum upon which is cut a spiral thread, the contour of this is the curve of flow over the "V" notch weir. The pitch of the thread increases in proportion to the flow through the notch, which increases rapidly with the head.

Above the drum is a horizontal bar traveling on pivoted rollers. A pen arm is attached to this bar which moves equal distances to the right or left with equal increments in the rate of flow. As the float rises or falls the pen makes a record reading in terms of pounds or gallons on a paper chart driven by clock work.

On the body of the metal drum, adjacent to the curve of flow, is a graduated scale on which may be read the amount flowing at any moment. The upper end of the

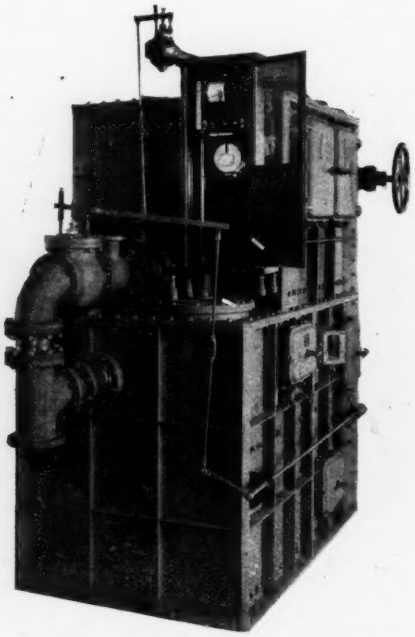


FIG. 6. WEBSTER HEATER EQUIPPED WITH V-NOTCH RECORDER

rack rod mentioned above carries a pointer indicating on a vertical scale the exact head in inches flowing over the notch. By this means the meter may be checked at any time while it is in operation by the application of a simple formula.

Besides the meters described above, there are, in some plants, automatic dumping scales which operate similarly to large steam traps but record the weight and number of dumps during any period. These should be used for weighing the hot water as it leaves the heater for the boiler feed pumps.

A combination of apparatus made by Warren Webster & Co., and by the Yarnall-Waring Co., and called an arrangement of the Webster feed water heater with the "Lea" V-notch recording meter, consists of a Webster feed water heater of either the standard induction type or the new preference cut-out type, the latter being equipped with a larger separator for the protection from oil of both the feed water heater and heating system, the heater being equipped, in any case, with the usual Webster features.

The connections for the feed water heater are the same as usual; but the water, after being heated in the

heating section, gravitates to the meter through a pipe connection outside of the shells of both devices. A regulating valve operated by a float within the water storage chamber of the meter, is installed in this outside connection. The outside connection may be direct, passing between the heater and the meter; but preferably it should be arranged with bypasses, so that the feed water heater or the meter, or both, may be cut out of service at any time for cleaning or inspection without interference with the other units.

The valuable feature of this combination of apparatus lies in the fact that there is no direct connection between the interior of the heater and the interior of the meter since there is a solid bottom in the heater where the shell joins the tank of the meter. By this method of construction there is no danger of flooding the weir of the meter (thereby assuring accurate results), at such times as the heater may be overflowing. Separation of the heater from the meter avoids irregularities in chart records due to pulsations of the exhaust, and avoids

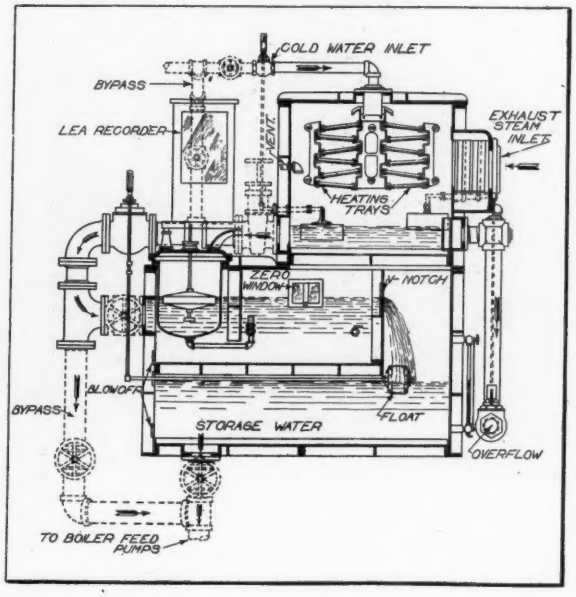


FIG. 7. SECTION THROUGH WEBSTER HEATER WITH METER ATTACHMENT

damage to the recording instrument due to sudden changes of exhaust pressure within the heater, or to water hammer.

A standard "Lea" V-notch meter is used in this combination, the extra storage type being employed, which provides an unusually large storage for hot water immediately available for pump demand. This arrangement may be made up in either the rectangular type or horizontal cylindrical or elliptical section type and of either cast-iron or wrought-iron construction.

The Precision patent water meter, made by the Precision Instrument Co., is another of the weir type. In this case the Yorke weir is employed which is so shaped that the flow is directly proportional to the head. From this it follows that as the head is recorded on the chart by a float submerged in flowing liquid and as the submergence of a float is proportional to the temperature of a liquid or its gravity, there is set up a compensating result. The Precision meter is used on the suction side of the pump and, therefore, in addition to compensating automatically for gravity and temperature, it is free from variations due to changes in pressure.

The Avery automatic water scale is a weighing device built on the even balance principle, having a dribble movement as the amount of water approaches the balance, a compensating lever and an inclosed counter. It is used to weigh the amount of water used for feeding the boiler before it enters the heater. The operation of the scale is entirely automatic, weighing and recording is done continuously and accurately regardless of supply pressure and temperature.

The G. E. water flow meter is, in principle, practically the same as the steam flow meter described under the head of measurement of steam. These meters are calibrated to give the correct flow under steady flow

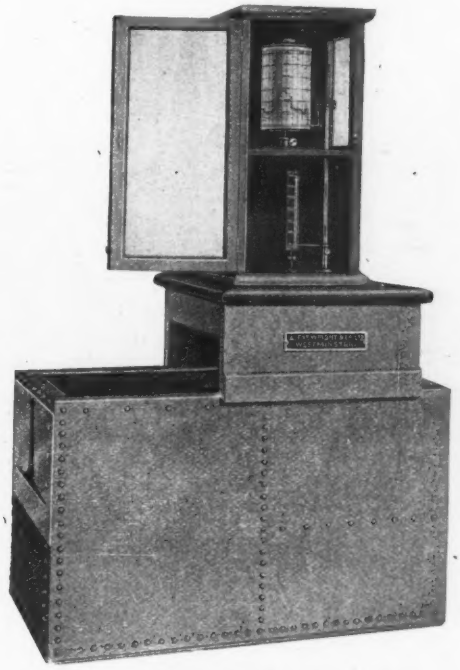


FIG. 8. THE PRECISION WATER METER

conditions such as from a centrifugal pump, but will give accurate results when measuring water delivered by reciprocating pumps, provided that the water flow at the point of installing the nozzle plug is not periodically intermittent; an air chamber of proper size will cause sufficiently steady flow.

An instrument called the Simplex register, made by the Simplex Valve & Meter Co., is readily adaptable for the measurement of the flow of water either over a V-notch weir, through a Venturi tube, or through a pipe provided with a Pitot tube. An arrangement with the V notch is shown herewith and is a combination well adapted to the measurement of feed water on the suction side of the pump. Where the water is under pressure, as when measuring the discharge from a pump, either of the other 2 forms is suitable.

In all cases the instrument indicates the rate of flow

at any instant, totals the quantity discharged and records the variation in flow. It is not necessary to locate the registering device below or even near the

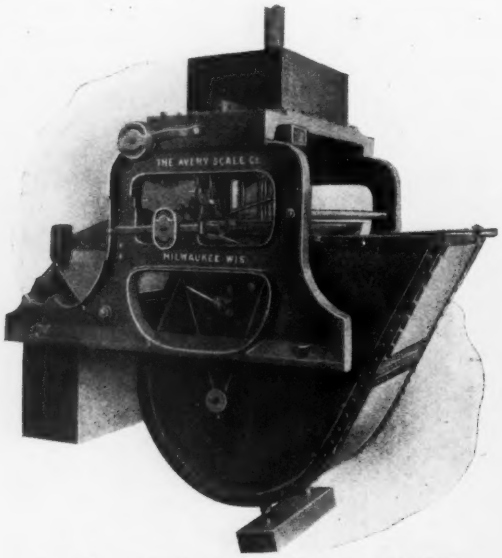


FIG. 9. AVERY AUTOMATIC WATER SCALES

weir, as illustrated; it may be placed in the most convenient place in the plant without affecting its accuracy and at the metering tank 2 indicating glasses may be

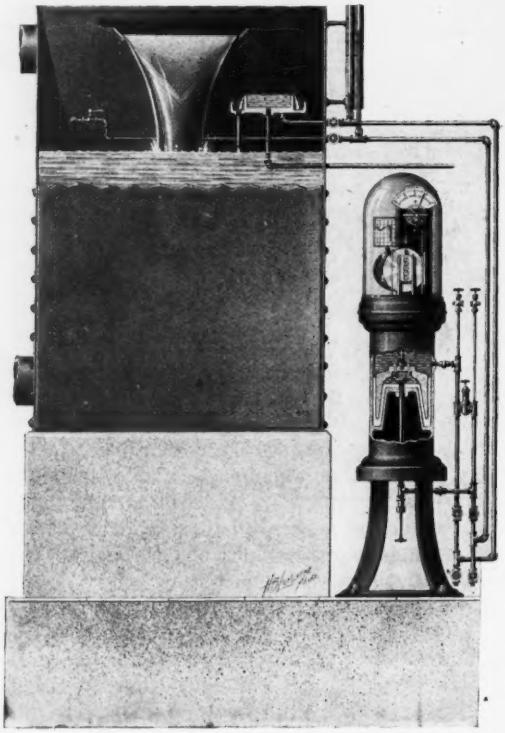


FIG. 11. THE SIMPLEX WEIR REGISTER

attached to show the rate of flow and check the instrument.

A manometer made by the Republic Flow Meters Co., for checking the flow of water through pipes, consists of a specially constructed Pitot tube connected through steel tubing to a mercury gage column which indicates the difference between the static and dynamic pressure in the pipe, thus giving a means by which the flow of water may be computed. The illustration shows the method of attaching the instrument to the discharge pipe of a centrifugal boiler feed pump.

In case there are no other means in the plant for weighing the water, it is well to calibrate the capacity

FIG. 10. G. E. WATER FLOW METER

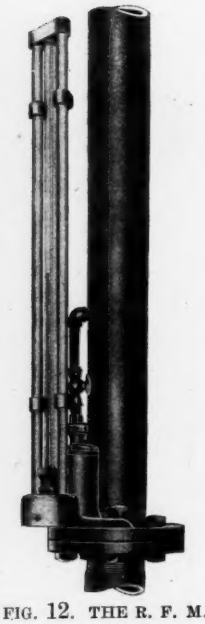


FIG. 12. THE R. F. M. MANOMETER

of plunger type boiler feed pumps, and by putting a stroke counter upon the pump a close estimate of the amount of water fed can be obtained. By this method, of course, there will be some inaccuracy due to slip and leakage of the pump, as well as variation due to temperature, but it is decidedly better than nothing, and will give the engineer data to approximate the evaporation per pound of coal.

RADIATION FROM bare pipe will be about 3 B.t.u. per hour for each square foot of exposed surface, per degree difference in temperature between steam and external air. With 1½ in. effective insulation, this may be reduced to from 0.3 to 0.4 B.t.u. The reduction varies with the size pipe and thickness of insulation. For 100 lb. and 60 deg. air temperature, on 2-in. pipe with ½-in. insulation, it will be 0.77; with 1½-in. covering, 0.41 B.t.u. For 4-in. pipe, ½-in. covering, 0.68; for 1½-in. covering, 0.335 B.t.u. For 6-in. pipe, ½-in. covering, 0.655; for 1½-in. covering, 0.310 B.t.u. For 8-in. pipe, ½-in. covering, 0.632. for 1½-in. covering, 0.297 B.t.u. For 10-in. pipe, ½-in. covering, 0.629; for 1½-in. covering, 0.287 B.t.u.—From the book Steam.

Cushion on Flow Meter

To Get Steady Record on Single-Acting Pump Line. By M. C. Saeger

DIFFICULTY IN obtaining a true line from which an average flow can be calculated, is found where single-acting pumps are in operation, as the pulsation in the flow, due to the falling of pressure at the end of each stroke, affects the indicating chart, as in Fig. 1. From this chart it is almost impossible to find a true average for each hour.

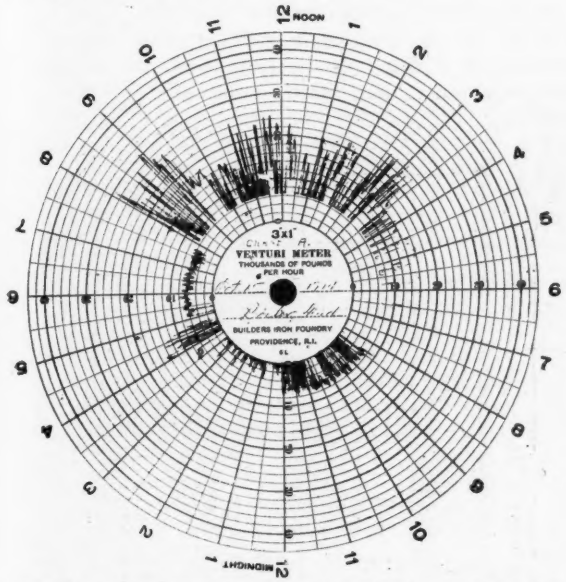


FIG. 1. FLOW METER CHART WITHOUT CUSHIONING CHAMBER

This fault may be overcome by the aid of a cushion chamber located between the pump discharge and the flow meter.

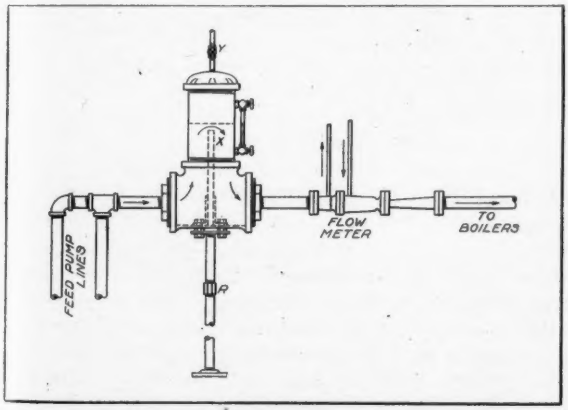


FIG. 2. ARRANGEMENT OF CUSHION CHAMBER ON FLOW METER LINE

Figure 2 illustrates a convenient method, which has been successfully tried out, for cushioning a 3-in. boiler feed line, and the result will show in the chart, Fig. 3, from which the hourly average can be seen distinctly.

For the cushion chamber a 10-in. galvanized tee with 10 by 3-in. reducing fittings at each end, has a 10-in. galvanized nipple, 24 in. long, with a 10-in. cap fitted to the top. A baffle plate, made of ¼-in. iron, located at X, is bolted to the bottom of the tee and extends 12 in. into the nipple.

Bolts holding the baffle to the base of the tee extend through the casting and flange on the lower pipe support for tee. R is a right and left coupling to bring the entire weight of the tee on the vertical pipe support. Line Y is for charging the cushion chamber with air pressure which should exceed the pressure on the feed water line.

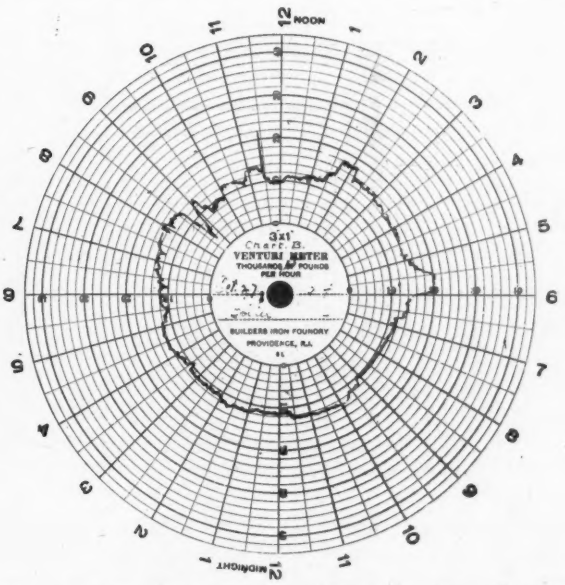


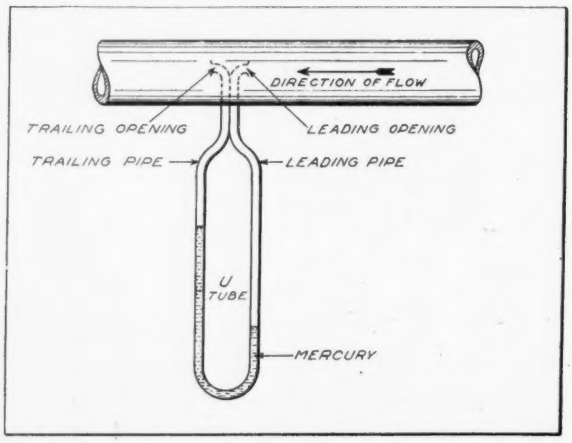
FIG. 3. FLOW METER CHART AFTER CUSHION CHAMBER WAS INSTALLED

Steam Flow Measurement

BOILERS operated at full load rating or slightly above are found to give their highest efficiency. Without definite knowledge of the output of the boiler the fireman is required to guess at the load on the different boilers, and even though he may know the total load on the plant, some of the boilers may be overloaded, others under-loaded, cutting down the efficiency perhaps several per cent which could easily be gained if only definite knowledge were available.

In the most efficient modern plants a steam flow meter of some description is placed on each boiler, a load indicating sign is put in the boiler room which gives the total load delivered to the switchboard, and the foreman of the boiler room divides the load among the boilers in such proportion as to give the highest over-all efficiency. With proper instruments this is made a matter of calculation after tests have been run, and a schedule can be made by which to run the boilers, putting the operation entirely out of the class of guess work, and eliminating, to a great extent, the personal element which ordinarily plays such an important part around the boiler room.

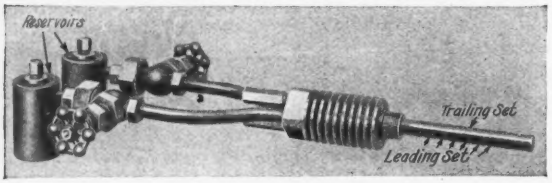
The principle upon which several of the flow meters used in power plants operate is that of the Pitot tube, which, in its simplest form, consists of a U tube containing mercury with both branches running into the steam pipe, one opening in the direction of flow, the other in the opposite direction. When the flowing steam impinges against the leading opening it sets up a pressure in the leading pipe to the U tube which equals the static pressure plus the pressure due to the velocity head. The drag of the steam over the trailing opening lowers the pressure in the trailing pipe, and, due to the differential pressure the mercury in the U tube is deflected until the unbalanced column balances the differential pressure.



ELEMENTARY FORM OF PITOT TUBE AND METER

The difference in the heights of the columns in the 2 branches of the U tube is then proportional to the flow of the steam through the pipes.

In the G. E. Steam Flow Meter, made by the General Electric Co., the principle of the Pitot tube is used,

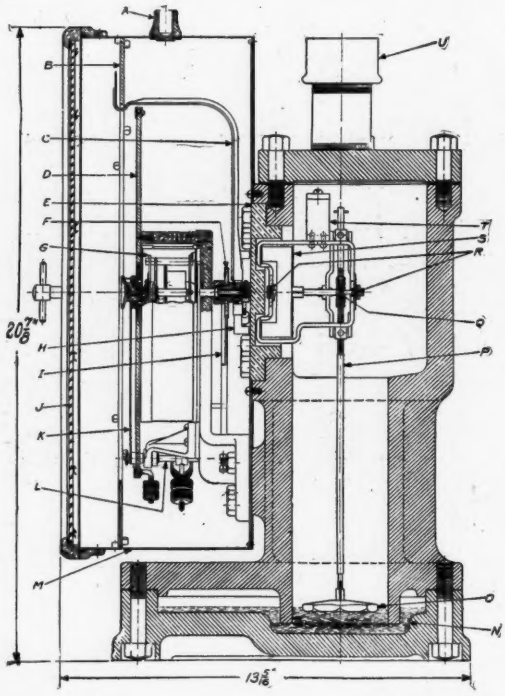


NORMAL VELOCITY NOZZLE PLUG OF THE G. E. STEAM FLOW METER

but especially designed nozzles are employed for different purposes to which the meter may be put. What is known as the normal velocity nozzle plug is composed of a double conduit tube extending across the pipe diameter, each conduit having a separate set of openings. The leading set of openings extends the length of the tube across the pipe diameter and faces against the direction of flow. The trailing set of openings is located midway between the ends of the tube and at the center of the pipe diameter and faces in the direction of flow. The differential pressure due to the flow is transmitted to the mercury in the U tube of the meter.

The arrangement of the openings in the plug are such as to give a mean velocity pressure, due to the flow, across the full diameter of the pipe.

In all types of G. E. flow meters orifice tubes are used to measure the flow in pipes 2 in. or less in diameter. The orifice tubes consist of a pipe tapered internally at both ends to form an orifice near the center of the tube. When the steam flows through the tube there is a temporary reduction of pressure in the orifice which is proportional to the velocity. A U tube containing mercury is attached with one branch at the orifice and the other to connections at the ends of the orifice tube as shown in the illustration. Due to the differential pressure the mercury in the U tube is deflected until the unbalanced column exactly balances the differential pressure.



SECTIONAL VIEW OF THE G. E. INDICATING, RECORDING FLOW METER

The same type of recording or indicating mechanism is used with both of these types of meter, and consists essentially of an iron float attached to a circular rack resting on the surface of the mercury in the large leg of the U tube. The rack engages a pinion mounted on a shaft carrying a large horse-shoe magnet which has its pole faces near the copper plug bolted on the body castings. The rack carrying the float and the pinion is so mounted as to be self-alining and will gradually rotate, causing equal wear on the pinion teeth. Another horse-shoe magnet is mounted with its pole faces near the copper plug and with its axis of rotation in alinement with the shaft carrying the horse-shoe magnet inside the meter body. The indicating needle is attached directly to the outside magnet. These instruments are made to indicate and record the steam passing any particular point in the steam piping. Instruments which

merely indicate the flow of steam are the same in principle, but the mechanism for operating the recording mechanism is omitted.

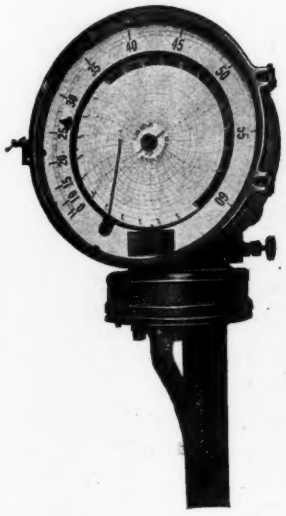
The RFM flow meter, manufactured by the Republic Flow Meters Co., is equipped for indicating, integrating and recording purposes; it is possible to place the reading dials at any distance from the pipe in which the flow is measured.

The impact exerted by a flowing mass of steam upon perforated tubes placed in the direction of the flow, is counterbalanced by the displacement of a liquid column to a height equivalent to that flow. The rise and fall of the liquid column, in this case, a confined body of mercury, is made to engage and disengage suitable conductors of an electric circuit, in direct proportion with the increased flow of the fluid in the pipe where the perforated or meter tubes are placed. The conductors are arranged so closely to one another that a continuous variation in the flow of fluid in the pipe produces a corresponding variation in the current transmitted by the electric circuit.

Accordingly, the total amount of current passing through the circuit is the exact equivalent of the total amount of fluid passing through the line, and the instantaneous flow of current through the circuit is equivalent to the instantaneous flow of fluid through the line. This current and consequently the flow of the fluid in the pipe is measured by an instrument on the principle of a wattmeter, and indicated or recorded by an instrument on the principle of an ammeter.

The illustration shows the construction of the RFM meter in sectional view. The meter tube inserted in the pipe line transmits the differential pressure through the static and dynamic reservoirs into the steel casing and mercury well respectively. The electric circuit has one terminal connected to the steel casing and mercury well, and the other terminal to the set of conductors, overhanging the mercury column in the casing.

As the column rises, due to the differential pressure caused by the impact of the flow, the conductors coming in contact, transmit through the electric circuit an amount of current in proportion with the height of the rising column. Each conductor in the set has a specific resistance regulating the current to correspond with the impact of the flow of the fluid. The instruments on the meterboard are deflected by this current, the readings of which are given in the proper units of the fluid measured.



TYPE OF G. E. INDICATING, RECORDING FLOW METER FREQUENTLY USED ON BOILERS

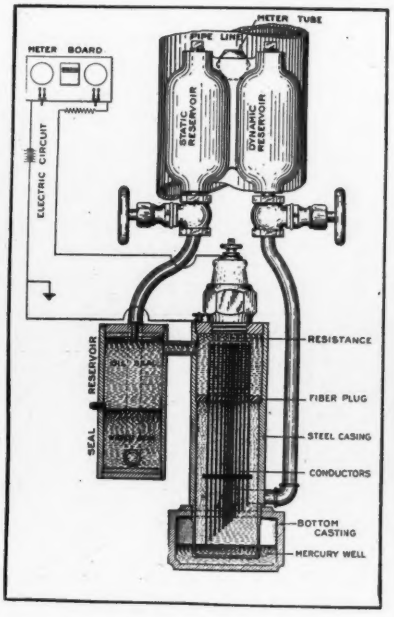
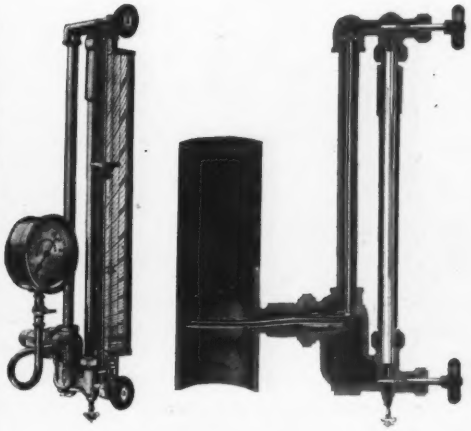


DIAGRAM OF THE R. F. M. STEAM FLOW METER



EXTERIOR AND CROSS SECTION OF THE GEBHARDT STEAM METER

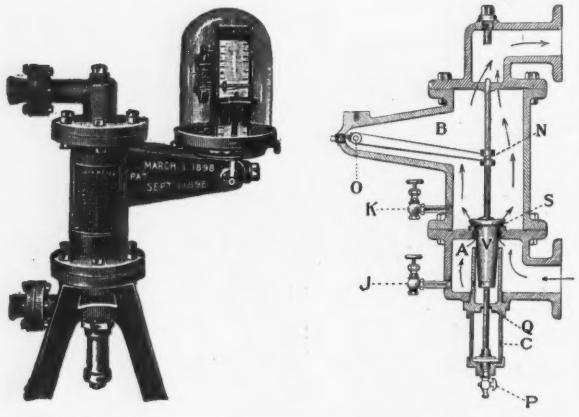
The Gebhardt portable steam flow meter is also manufactured by this company. It is a simple, accurate and convenient instrument for indicating the flow of steam through pipes of all diameters at all working conditions of pressure and temperature.

The connection of the Gebhardt meter to the steam pipe requires only the insertion of a threaded plug supplied with the meter. It requires no fitting and when connected shows directly the pressure in the line, velocity of the steam and the amount of discharge in pounds per hour.

The meter consists essentially of a water gage glass fitted to special gage holders. These holders are constructed so that the water of condensation will collect in the gage, the height of the water column being a direct measure of the weight of steam flowing in the pipe to which the apparatus is connected. The meter is attached to the pipe by means of a nipple, and is adapted to pipes of any size and in any position.

The principle upon which the St. John steam meter, made by G. C. St. John, operates is that with a uniform difference of pressure on 2 sides of an orifice through which steam is flowing at a constant initial pressure, the

quantity of steam passing bears a direct relation to the size of the orifice. A meter valve in the instrument operates in such a manner that when it is in its lowest position the valve is closed and no steam is flowing; when the valve is raised, the space between the tapered plug and the seat increases from zero to a maximum, and a rate of increase depends upon the taper of the plug. The space between the tapered plug and the seat is then the orifice through which the steam flows and the size of the orifice varies as the plug rises and falls, which occurs with the increase or decrease in the quantity of steam flowing. The taper of the plug is such that the amount of steam passing through the orifice per hour is directly proportional to the rise of the meter valve. The motion of the meter valve is transferred outside the meter case to the pencil arm, which carries



EXTERIOR AND CROSS SECTION OF THE ST. JOHN STEAM METER

the pencil and pointer, by a lever arm inside the casing, supported at the center of rotation by a small spindle. The needle moving over a brass dial shows the quantity of steam flowing in horsepower, and the pencil moving with the needle makes a record on a paper ribbon operated by clockwork. The meter may be used with either live or exhaust steam and at pressures above or below atmospheric.

Temperature Readings

EVERY boiler plant should be supplied with thermometers, one placed outside of the building and the other inside where they may be easily and readily seen and read by the firemen.

From a theoretical standpoint, unless some auxiliary heating device is employed, the temperature of the fire room should be equal to that of the outside atmosphere, as every degree of heat which the boiler room has in excess of that of the outside represents so much loss due to radiation of the boiler, settings, heaters and piping. It can readily be seen, therefore, that the less the radiation loss in a boiler room, the nearer its temperature will be to that of the outside atmosphere, and it should be the aim of every man in charge of boiler plants so to protect his equipment that a minimum of loss due to radiation occurs.

Drop of Temperature Through Combustion Path

THE HIGHER the initial furnace temperature, the greater will be the efficiency of the heating surface, since the heat transmitted varies almost directly with the difference between average temperature of the water and the furnace gases. If the heating surface is properly distributed so that the final temperature of the escaping gases is constant, the efficiency of the boiler and furnace will increase as the initial temperature increases, although not in direct proportion. It is almost impossible to give any set rule regarding the proper distribution of the heat of the gases throughout the settings as this varies with the types of boiler, furnace, methods of baffling and kind of fuel burned. For economical operation, it is safe to accept a flue temperature of 500 deg. F. or less.

In Table I may be found the results of temperature observations at various points in the path of the gases through a 650 hp. Babcock & Wilcox boiler operating under various loads.

TABLE I. TEMPERATURE OBSERVATIONS AT VARIOUS POINTS IN THE PASSAGES OF A 650-HP. B. & W. BOILER OPERATING UNDER VARIOUS LOADS

Per Cent of Rating	Boiler and Grate Efficiency	Temperature, Degrees F						
		Furnace Temperature.	Middle First Pass	Top First Pass	Top Second Pass	Middle Second Pass	Middle Third Pass	Flue
117.3	78.5	2336	866	655	619	511	471	455
126.7	79.6	.....	893	689	646	526	485	473
128.6	79.8	2420	888	681	635	521	481	468
131.0	77.1	2455	899	682	642	519	479	468
131.0	75.3	2430	913	694	655	512	486	475
137.4	77.6	.....	956	723	660	547	512	492
142.2	76.5	.....	939	700	634	523	493	475
185.3	72.7	2530	1051	751	700	578	541	519

In the case of a 300-hp. Badenhausen water-tube boiler, it was found that the following temperatures existed: In the furnace, 1857 deg. F.; at the end of the first pass, 875 deg. F.; at the end of the second pass, 608 deg. F., and at the end of the third pass, 518 deg. F.

Feed Water Heater Temperatures

FEED WATER in an open heater with a sufficient supply of exhaust steam may reach the same temperature as the entering steam, but due to the fact that not much more than atmospheric pressure is carried in this type of heater, this temperature can not go above 212 deg. F.

The temperature of the water entering a heater can not be controlled, as this depends upon the nature of the source of supply. The temperature of the water leaving the heater depends upon the heat content of the steam entering the heater, the temperature of the entering water and the ratio of weight of exhaust steam to that of feed water, and can, therefore, to some extent be controlled and regulated as desired. Due to the variation in the quantity of exhaust steam supplied and the water demanded by the boiler, it is difficult to maintain the water leaving the heater at a temperature of 212 deg. F. without discharging the surplus steam into the atmosphere or causing it to be passed into a condenser.

Good practice, followed in many power plants, is the use of thermometers on the water inlet and the outlet lines of feed water heaters, either in the form of the

ordinary mercury indicating thermometer placed in a well or, if a more elaborate system of operation is in force, recording instruments may be employed, thus obtaining a continuous record of the performance of the heater.

Economizer Temperatures

Economizers may be considered as the connecting link between the feed water heater and the boiler, as in the heater the temperature of the feed water is raised to nearly 212 deg. F. at a pressure a trifle more than one atmosphere, while the economizer takes this water and, by utilizing the remaining available heat in the flue gases, raises the temperature of the feed water nearly to that of the water in the boiler. The temperature of the water entering the economizer depends upon the temperature at which the water leaves the heater, or if not preheated upon the temperature of its source. Rise in temperature of the water in the economizer depends upon the square feet of economizer heating surface per boiler horsepower, temperature of entering water, and ratio of weight of feed water to pounds of flue gas.

TABLE II. TYPICAL ECONOMIZER PERFORMANCES

Number of Plant	Number of Economizer Tubes Installed	Temperatures, Deg. Fahr.					
		Gases Entering Economizer	Gases Leaving Economizer	Water Entering Economizer	Water Leaving Economizer	Rise in Temp. of Water	Actual Saving in Fuel, per cent
1	160	435	279	84.2	196.2	112.0	12.5
2	....	416	254	40.0	185.4	125.4	13.8
3	960	620	293	101.0	237.0	136.0	18.3
4	520	548	295	96.0	200.0	104.0	9.2
5	520	603	325	93.5	203.8	110.3	9.7
6	384	369	245	103.0	232.6	99.6	12.4
7	448	537	326	71.2	203.4	132.2	17.5

A method of approximating the rise in temperature of the water where the final temperature of the flue gas is known, is to assume 0.5 deg. F. rise in the feed water for each degree reduction in the temperature in the flue gas. This is determined on the basis that approximately 20 lb. of flue gas are generated for each pound of combustible and that 10 lb. of water are evaporated per pound of combustible; that is, 2 lb. of flue gas are generated for each pound of feed water delivered to the boiler. Assuming a specific heat of 0.25 for the flue gas, this gives 2 times 0.25, or 0.5 deg. F. rise in temperature of the feed water for each degree reduction in the flue gas temperature.

Little can be said relative to the temperature of the gases entering and leaving an economizer. In a given installation, the temperature of the gases entering the economizer depends upon the nature of the load, whether steady or varying, upon the amount of heat absorbed by the boiler heating surface, and the condition of the settings and gas passes. The temperature of the outgoing gases with a given initial temperature depends upon and varies with the number of square feet of economizer heating surface and quantity of water heated.

The accompanying table of Economizer Performances shows the inlet and outlet temperature of gases and water in 7 typical economizer installations.

After determining the temperatures which exist at various points when the plant is operating satisfactorily, any wide variation from these serves as a quick warning that something probably needs attention to reestablish economical conditions of operation.

Gas Analysis

When coal is completely burned, the carbon, C, unites with the oxygen, O, of the air, forming carbon dioxide, CO_2; and if this operation is properly carried out, complete combustion will result, and all the heat possible will be produced from the fuel. If this operation is not properly carried out, there is either incomplete combustion, accompanied by smoke and the formation of carbon monoxide, CO, due to an insufficient amount of air, or an excess of nitrogen and consequent cooling of the hot gases due to too much air, wasteful because the heat is carried off by this excess air instead of by the water in the boiler. It becomes evident, therefore, that some means should be employed whereby these conditions may be detected and corrected.

For determining the percentages of CO_2, CO and O, the Orsat apparatus is generally used. In its simplest form, this consists of 3 double pipets connected to a manifold which in turn is connected to a graduated measuring tube. Gas from the furnace is passed through each of the 3 pipets containing reagents which readily absorb all of the CO_2, CO and O present.

The gas is measured before and after being passed through each pipet, the first generally containing a reagent made up of 1 part caustic soda, OH, and 2 parts by weight of distilled water. In passing through this solution, the carbon dioxide is absorbed and the decrease in volume of the gas sample expressed as a percentage of the original amount of carbon dioxide, CO_2, present. The sample is then passed into the second pipet containing an alkaline solution of pyrogallic acid or sticks of phosphorous and, as before, the decrease in volume expressed as a percentage of the whole is the amount of oxygen, O, present. A hydrochloric acid solution of cuprous chloride is used in the third pipet to absorb the CO. As the volume of the gas is carefully measured in the measuring tube shown on the right of the accompanying illustration before and after being passed through the pipet, it is necessary to have the sample under atmospheric pressure accomplished by raising or lowering the water bottle shown on top of the case, until the level is the same in bottle and measuring tube.

To increase the surface over which the reagent can act, the pipets are filled with small glass tubes.

In addition to the hand-operated analyzers just mentioned, recording instruments are on the market which take a sample of gas about once in 3 min., analyze it and record the results on a chart.

For obtaining a gas sample, it is advisable to place in the passage of the waste gases a ¾ or 1-in. iron pipe plugged and having small holes drilled into it at one end or cut off at an angle of 45 deg. Whether taking this sample for a recorder or a general test, it is important to see that the pipe is thoroughly cleared of all air which in the case of the Orsat apparatus is done with a rubber aspirating pump. Recording instruments, as a rule, are provided with some form of arrangement such as a water vacuum pump, keeping the gas fresh up to the inlet.

Analysis made of samples of gas taken at regular stated intervals is preferable to a mixture of samples

taken during a period of a number of hours, as in the former method it is possible to know under what furnace and operating conditions the samples were taken and note the results, while in the latter method, nothing but an average value is obtained without any reference to operating conditions.

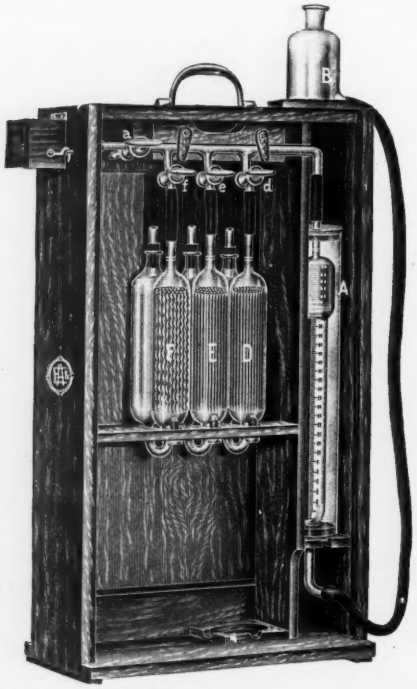


FIG. 1. ORSAT APPARATUS FOR CO_2 ANALYSIS

Theoretically, the higher the percentage of CO_2, the less the waste of fuel, but, in practice, it is found that the highest possible efficiencies are obtained with percentages of CO_2 of from 10 to 17. Under normal operating conditions, correct furnace construction and a tight setting, the following percentages of CO_2 may be obtained, the average approximating the maximum within 3 per cent in hand-fired furnaces and within 1½ per cent in stoker-fired furnaces: Anthracite coal of good quality, 15 to 16 per cent; semi-bituminous coal of good quality, 14 to 15 per cent; bituminous coal of good quality, 13 to 14 per cent.

The principal symptom of incomplete combustion is the presence of CO, and to get a correct understanding of the possible loss due to CO in the products of combustion, we must remember: 1. That no relation exists between the percentage of CO_2 and CO contained in the products of combustion; gases low in CO_2 may be accompanied by a relatively high per cent of CO, and gases high in CO_2 may be quite free from CO; 2. That the loss due to incomplete combustion varies inversely as the percentage of CO_2, i.e., the loss of fuel due to a given per cent of CO is twice as great with 7 per cent of CO_2 as with 14 per cent of CO_2; 3. That in a properly constructed furnace in which a hot even fire is maintained, the maximum per cent of CO_2 can be realized without danger of appreciable loss due to CO.

The principal causes of high CO are, fire too thick; draft too low; insufficient combustion space; and uneven fire bed. The principal causes of low CO_2 are: leaky boiler setting; fire too thin; draft too strong; uneven fire; too much air admitted above the fire.

Leaky boiler settings are the most frequent cause of low CO_2, and since air entering through the cracks or

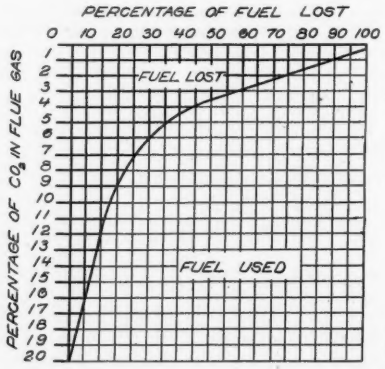

PERCENTAGE OF FUEL LOST
0 10 20 30 40 50 60 70 80 90 100
PERCENTAGE OF CO2 IN FLUE GAS
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
FUEL LOST
FUEL USED

FIG. 2. DIAGRAM SHOWING RELATION BETWEEN PER CENT OF CO_2 AND PERCENTAGE OF FUEL LOST

sifting through porous walls cannot aid combustion, the escaping gases may contain a high per cent of CO and thus greatly aggravate the loss.

The accompanying diagram based on the assumption that the furnace gases leave the main flue at normal

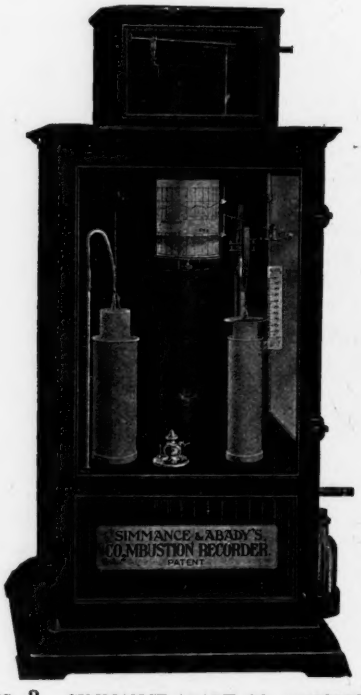


FIG. 3. SIMMANCE-ABADY CO_2 RECORDER

working temperatures, indicates the relation between the fuel lost and the percentage of CO_2. It will be noted that 10 or 12 per cent of fuel loss is unavoidable owing to the impossibility of discharging the flue gases at atmospheric temperature, but the diagram shows that the fuel loss increases as the percentage of CO_2 decreases.

CO_2 Recorders

Various types of instruments for the measurement and recording of the percentage of CO_2 in furnace gases are on the market.

In the accompanying illustration, Fig. 3 shows the Simmance-Abady CO_2 recorder. Figure 4 illustrates the general principle of this instrument, the operation of which is as follows: A continuous stream of water enters the reservoir *k* through inlet *x* and overflow at *o*, a portion of the stream flowing into tank *a* through pipe *f*, causing the bell float *b* to rise, at the same time permitting bell *d* of the extractor to fall. When float *b* reaches the top of its stroke, it raises valve stem *e*, trips the valve and causes the water to siphon out of a tank through the siphon tube *g*. The lowering of the water level allows the bell to sink, and as it descends it draws up the water-sealed extractor bell *d*, creating a partial vacuum under the latter.

Flue gas then flows from the source of supply through *p* and *h* into the bell. The mass of water discharged from siphon tube *g* into the small vessel *v* beneath, overcomes the counterweight *q*, closing balanced valve *h*, thereby entrapping a fixed volume of gas in the extractor bell. The stream of water continually flowing into tank *a* causes float *b* to rise and bell *d* to sink, as before. Lowering of bell *d* forces the entrapped flue gas through the caustic potash solution in vessel *m* into water sealed recorder bell *j*, the displacement of which is less than that of bell *d* by the volume of CO_2 absorbed in vessel *m*. The percentage of CO_2 in the flue gas is thus indicated by the position of the bell *j* with reference to the graduated scale *n*, samples being analyzed and the percentage of CO_2 recorded at 3-min. intervals. The pen mechanism is attached to bell *j* and records the percentage of CO_2. Small aspirator at *x* is for the purpose of exhausting gas continuously from the pipes connecting recorder and boiler, thereby insuring true samples at the time of absorption.

Another typical CO_2 recorder is the Uehling composimeter consisting primarily of a filter, absorption chamber, 2 orifices and a small steam aspirator. Gas is drawn from the usual source of supply by means of the aspirator, first through a preliminary filter located at the boiler, and then through a second filter on the instrument. From here the gas passes through the first orifice, through the absorption chamber, then through a second orifice to the aspirator, where it is discharged, the CO_2 being absorbed by the caustic potash solution in the absorption chamber. This reduces the volume and change in tension between the 2 orifices in proportion to the CO_2 content of the gas, this variation in tension being indicated by a water column and transmitted by suitable piping to the recording mechanism.

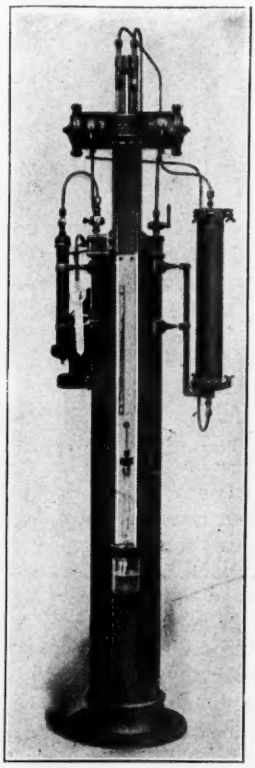


FIG. 5. UEHLING CO_2 RECORDER

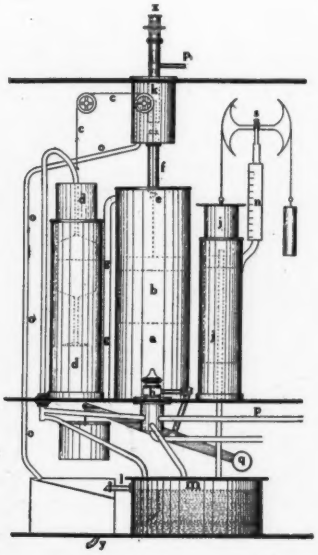


FIG. 4. GENERAL CONSTRUCTION, SHOWING PRINCIPLES OF OPERATION OF SIMMANCE-ABADY CO_2 RECORDER

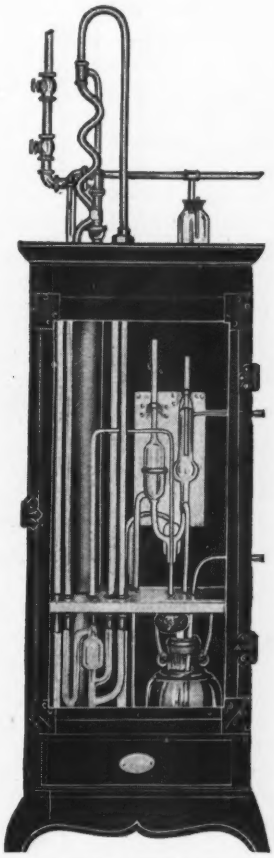


FIG. 6. HAYS AUTOMATIC CO_2 ANALYZER WITH SOOT FILTER AND CONDENSER

The Hays automatic CO_2 and draft recorder consists of 4 separate parts—the analyzer, the recording gage, a water pressure regulator and a combined soot filter and condenser.

By means of a system of tubes and a mercury valve, a definite quantity of gas is trapped off and passed through a vessel containing caustic potash in which the CO_2 of the flue gas is absorbed, the reduction in volume operating so as to show the exact percentage of CO_2 on the chart. Water rises and falls in these tubes, and by means of a mercury valve and a water overflow, the levels of all the liquids are automatically corrected at the end of each cycle of analysis.

Since the recording gage is separate from the analyzer, and is connected to it with copper tubing, the recorder may be located at a distance, for example, the gage might be located in the engineer's office and the analyzer installed in the boiler room. All that is necessary to put the recorder in operation is to provide the required water and gas connections and connect the analyzer with the recording gage.

Running water furnishes the motive power for the recorder, and, a pressure regulator is furnished with the apparatus for the purpose of maintaining a constant speed, water being conducted to the regulator from any convenient source, and led therefrom to the analyzer.

Since a uniform temperature is essential to accuracy, because of the expansion and contraction of the gases, the gas measuring and gas absorbing parts are water jacketed in the same chamber, the water being kept in constant circulation to insure uniform temperature.

To remove soot and other foreign matter, the gas is passed through a filter supplied for this purpose, and any water vapor in the gases is condensed before they enter the filter. The gases are taken from the last pass of a fire-tube boiler, through a 1-in. pipe which leads direct to the condenser and filter, and from the filter the gases are carried by a ½-in. pipe to the analyzer.

Caustic potash, used for the absorption of CO_2, should be changed about once a month, and new filtering material should be placed in the filter when necessary. Analysis is made at intervals of about 3 min. and the chart upon which both CO_2 and draft in uptake are recorded, covers a period of 24 hr.

The Sarco automatic combustion recorder makes continuous and automatic analysis of flue gases, determining and recording on a chart the percentage of CO_2 present.

Operated by a small stream of water at a head of 4 ft., the recorder traps off samples of gas at regular intervals and brings them into contact with a solution of caustic potash, which absorbs the CO_2. The remaining gas actuates a float which causes a pen to record on a drum the actual percentage of CO_2 in the respective sample.

The gas when analyzed, leaves the recorder by a set of tubes entirely separate from those through which the samples are obtained, thus avoiding all possibility of mixing the old with the new.

No attention is required after the apparatus is started, as it operates automatically, necessitating only the changing of charts every 24 hr. and the renewal of the potash solution every 2 or 3 weeks.

Treatment of Water

FOR the proper chemical treatment of boiler feed water it is necessary to make frequent and careful analysis of the water and prepare the treatment accordingly. This is especially true where surface water, such as that from lakes, rivers, and creeks, is being used, which is subject to decided changes due to surface affluents carried into them by rains, or melting snow. It is not uncommon in some localities to find a stream which varies to a decided extent during moderately short intervals, going from an alkaline to an acid condition within a few weeks, an analysis of which it is advisable to make from every 6 weeks to 3 months. In the case of water coming from subterranean streams subject to but little change, a yearly analysis is sufficient. When using a new well, samples should be analyzed every 30 days for the first 6 months, owing to the fact that the character of the water is subject to considerable change during this period.

Where a scale preventive or remover is used, the function of which does not depend upon chemical actions, an analysis is unnecessary, as the treatment in such cases is of mechanical rather than a chemical nature.

Substances generally found in boiler feed waters are: silica or sand, $Si\,O_2$; iron carbonate, $Fe\,CO_3$; aluminum colloidal hydroxide, $Al\,(OH)_3$; sodium chloride and sulphate, $Na\,Cl$ and $Na_2\,SO_4$; potassium chloride and sulphate, KCl and $K_2\,SO_4$; lime, or calcium bicarbonate, $Ca\,(HCO_3)_2$; calcium chloride, $Ca\,Cl_2$; calcium sulphate, $Ca\,SO_4$; magnesium bicarbonate, $Mg\,(HCO_3)_2$; magnesium chloride, $Mg\,Cl_2$; magnesium sulphate, $Mg\,SO_4$; free carbon dioxide or carbonic acid gas, CO_2; hydrogen sulphide, H_2S; organic material such as dissolved vegetable and animal matter. When classified according to the amounts present, these substances are placed in 2 groups, the calcium and magnesium salts in one and the rest in the other. In the average water, the amount of calcium salt varies from 5 to 25 grains per gallon and the magnesium salts from 1 to 5 grains, while the other substances are in much smaller quantities generally running from 0.01 to 0.1 grain.

Bad water may cause scale, may corrode or pit the boiler or may cause foaming or priming. By analyzing scale from a boiler it is found to contain traces of silica, a little iron and aluminum salts, but mostly calcium and magnesium salts. In fact, boiler scale is usually caused primarily by calcium and magnesium salts; if these are naturally absent, as in soft water, or have been removed by treatment, scale trouble will not exist.

Boiler scale varies from the hard kind requiring the use of a cold chisel to remove it, to a soft composition easily scraped loose or blown off. Hard scale contains as its basis the sulphates and chlorides of calcium and magnesium. It does not deposit at once on heating the water, but comes out slowly as the result of saturation due to concentration, or due to a decrease in solubility brought about by increased temperature. Most substances are more soluble in hot water than in cold water. Calcium sulphate, and under certain conditions, magnesium hydroxide, are, however, less soluble in hot than in cold water, and as a result, may readily be precipi-

tated, and some waters fairly purified by preheating.

Soft scale or sludge, caused by the presence of calcium and magnesium carbonate contains carbonic acid gas which is given off when the solution of the bicarbonate is heated, half of the gas being set free, the other half held in combination. The carbonate remaining after the gas has been driven out of the bicarbonate is insoluble, so that when water containing the bicarbonate is heated, the carbonate is formed and precipitated as a soft sludge, this precipitation taking place on merely heating the water, not requiring concentration from boiling. The chemical reaction of this is expressed as follows: $Ca(HCO_3)_2$ heated $= CaCO_3 + H_2O + CO_2$.

Corrosion of the boiler is the opposite of scaling. A few waters are distinctly acid and it is easy to see why they dissolve iron, but it is not so easy to determine from the analysis thereof whether they will pit the boiler or not. If the water contains a quantity of magnesium chloride, it will cause corrosion, because at high temperature the magnesium will react with all of the oxygen and half of the hydrogen of some of the water forming insoluble magnesium hydroxide. This leaves behind half of the hydrogen of that part of the water and all of the chloride of the original magnesium chloride, which readily unite, forming hydrochloric acid. This may be shown chemically by, $MgCl_2 + 2H_2O = Mg(OH)_2 + 2HCl$.

Other compounds of magnesium act the same, though perhaps to a less extent.

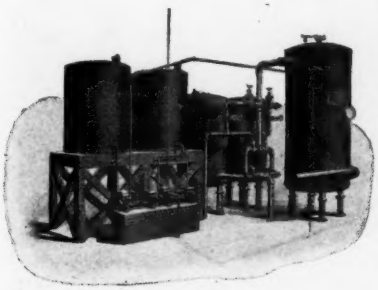


FIG. 1. THE WE-FU-GO INTERMITTENT SYSTEM OF WATER PURIFICATION

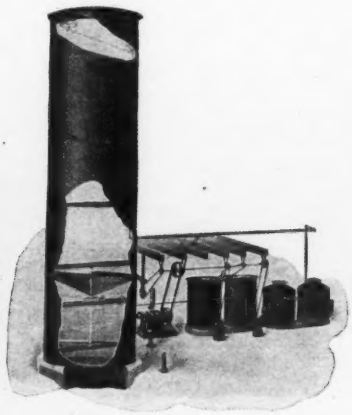


FIG. 2 THE WE-FU-GO CONTINUOUS SYSTEM OF WATER PURIFICATION

FIG. 3. THE SCAIFE SYSTEM

Compounds

Within the last few years, the chemical treatment of boiler feed waters has been remarkably developed. The 2 most common systems of chemical treatment involve the use of boiler compounds and purifying plants. The object of treatment with boiler compounds is to neutralize the effects of the impurities in the feed water or to change them into others less objectionable and easily removed. When properly compounded and introduced into the boiler, such preparations are of great benefit and practically overcome the deleterious effects, but when improperly used they may produce even greater trouble than the impurities they are expected to eliminate.

Boiler compounds may be divided into 3 classes: The first class converts the scale-forming elements into new substances which will not form a hard, resisting scale and which are readily removed by skimming, blowing off or by some form of mechanical tube cleaner. Feed water containing sulphates of lime and magnesia will form a dense, tenacious scale, but if carbonate of soda, soda ash, be added in the correct amount, the sulphates are converted into insoluble carbonates which are precipitated and form scale varying from a more or less porous crust to a mud. The resulting sulphate of soda remains in solution and does not harden unless allowed to concentrate, which may be prevented by frequent blowing down. An excess of soda is apt to cause foaming and at high temperatures is liable to attack the inside of gage glasses. Bisodium, trisodium phosphate, sodium tannate, fluoride of sodium, sugar, etc., may be used instead of carbonate of soda with equally good results.

The second class of treatment envelops the newly precipitated scale-forming crystals with a surface which prevents them from cementing together. The substances used to bring this result about are starches, woody fibers, dextrine, slippery elm, etc.

The third class are those preventing the formation of hard scale by a solvent or rotting action, as kerosene and petroleum oils. These are sometimes used with good results to prevent scale formations in boiler, and are ordinarily fed to the boiler with the feed water, drop by drop through sight feed apparatus. They are said to change the deposit of lime from a hard scale to soft but as the desired results are not always obtained, these oils are not used extensively. Kerosene should be used with care, as when a boiler is washed out and the kerosene placed therein, the resulting gas has been known not only to overcome men entering the boiler, but to cause explosions when brought into contact with an exposed flame.

Boiler compounds may be introduced continuously or intermittently, small quantities introduced continu-

ously or at short intervals being more effective than large quantities at long intervals. Continuous feeding is usually accomplished by connecting the suction side of the feed pump with a reservoir containing the compound in solution, arranged like a large cylinder oil lubricator. In large plants an independent pump is used to force the compound into the feed line. Intermittent feeding is done either by placing the compound in the boiler when open for cleaning or by temporarily connecting the suction of the feed pump with the reservoir containing the compound, thus feeding the compound at intervals.

Softening

When compounds are used, the treatment of the water generally takes place within the boiler while in modern methods of water softening this may be done before the water enters the boiler.

Softening water consists of the removal of those minerals causing hardness. These ingredients are removed by adding to the water chemicals which react with the hardening substances, changing them to insoluble compounds in which form they may readily be separated from the water. The chemicals generally used to precipitate the scale-forming substances are quicklime, soda ash, caustic soda and trisodium phosphate.

Calcium and magnesium bicarbonates dissolve only in water containing carbon dioxide gas. By freeing the water of carbon dioxide gas, accomplished by adding quicklime or caustic soda, the contained calcium and magnesium bicarbonates will be changed to carbonates and become insoluble. The quicklime added to the water absorbs the carbon dioxide gas and also becomes calcium carbonate. The lime added to precipitate the magnesium bicarbonate reacts with it as with the calcium bicarbonate, with the exception that the magnesium carbonate formed, being to some extent soluble in water, reacts with more lime and becomes magnesium hydrate.

When caustic soda is used, the reactions are identical to those where lime is used, with the exception that the caustic soda in absorbing carbon dioxide gas forms sodium carbonate, which being soluble in water, remains in solution. Sodium carbonate (soda ash) is used to precipitate calcium sulphate and calcium chloride, the reaction between calcium sulphate and soda ash forming insoluble calcium carbonate and sodium sulphate, which is soluble and therefore remains in solution. The calcium chloride and soda ash form calcium carbonate and sodium chloride (common salt), the latter remaining in solution.

To precipitate magnesium sulphate or magnesium chloride, it is necessary to use both lime and soda ash, the lime reacting with the magnesium sulphate forming insoluble magnesium hydrate and soluble calcium sulphate. The soda ash then acts with the calcium sulphate as described above.

Iron and aluminum bicarbonates react the same as does calcium bicarbonate with lime.

In the process of softening, it is necessary to make a chemical analysis of the water so as to determine the amount of chemicals required to produce the desired degree of softness.

In the We-Fu-Go system of purification, 2 or more treating and settling tanks, equipped with mechanical stirring devices operated by power, a reagent or chemical mixing tank with mechanical stirring device and pump for introducing the reagents into the treating tank are used.

The treating tanks are filled alternately with water; while a tank is filling, the reagents are introduced and thoroughly mixed with the water by means of the mechanical stirring devices consisting of a specially designed paddle, which not only mixes the reagents with the water but stirs up from the bottom the lime sludge of the preceding purification. This sludge floats in the water, hastens the chemical reaction and causes the new finely divided precipitate to form large flakes heavy enough to settle quickly as soon as the water stops moving.

After a tank is filled, the stirring device is stopped and the water permitted to stand to allow the precipitate to settle, the softened water being taken out of the tank by means of a hinged floating outlet pipe, arranged to rise and fall with the level of the water so that the water is always drawn from the top. While one tank is being filled, treated and settled, the other is supplying treated water and by the time it is empty, the first tank is ready for use, thus securing a constant supply of treated water.

Pipe connections to fill the tanks and wash the sludge therefrom are placed in the bottom. In order to wash the settling tanks, which need be done only when the sludge becomes deep enough to interfere with the stirring, it is necessary only to open the valves to the sewer and drain the tanks.

The We-Fu-Go continuous system consists of a tower tank containing separate lime reaction, soda reaction and settling compartments with mechanical stirring devices in the reaction compartments; tank for slaking lime and dissolving soda or other reagents; lime and soda solution tanks with stirring devices and pump for introducing the solutions into the reaction compartments.

Treatment in this system is automatically regulated to the quantity of water passing through, the speed of the pumps introducing the reagents being governed by the volume of water entering the system.

Water enters the lower compartment of the tower tank, where it is treated with the first reagent, then passes into the second compartment where it is treated with the second reagent. From the second compartment, the water passes into the upper or settling chamber, whence it flows to filters through a floating outlet pipe, which acts as a regulator for the water entering the system.

The We-Fu-Go system of water purification is the product of the Wm. B. Scaife & Sons Co., of Pittsburgh, Pa., also makers of the Scaife system.

This system is intended to treat hot water under pressure and consists of precipitating tanks, pressure filters, reagent solution tanks and pumps.

Water from the heater enters the precipitating tanks under pressure, where the reagents are introduced, and then passes to the filters. In this system of treating

water under pressure and at temperatures of at least 175 deg. F., the reactions are practically instantaneous and complete.

The Kennicott system of feed water purification is of the continuous type. Hard water enters the softener through an inlet pipe, and is discharged into a raw-water box from which it passes over a water wheel, thus generating the necessary power to maintain the reagents in constant agitation. Thence the raw water passes into the top of a large inverted cone, where it is thoroughly mixed with the reagents which are dissolved in the mixing tank located at the ground level, and by means of a pump elevated to the chemical tank above.

The reagents are apportioned to the amount of raw water coming into the dividing box, and as the head of this stream varies directly with any fluctuation of the main hard water stream, the 2 streams are constantly

FIG. 4. SECTIONAL VIEW OF KENNICOTT TYPE B-1 WATER SOFTENER

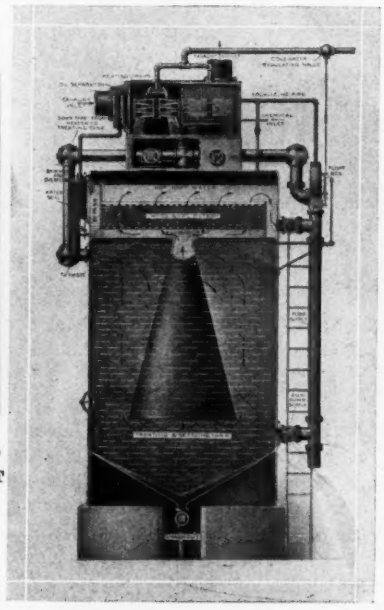


FIG. 5. THE SORGE-COCHRANE WATER SOFTENING SYSTEM

maintained in the same proportion to each other. In the dividing box this small stream is again divided by a slide directing one part of the water back into the hard water stream, and the rest, which determines the rate of flow of the chemicals, into the regulating tank. As the level of the water in this tank rises, a contained float rises also and by means of a connecting chain, lowers the mouth of the lift pipe in the reagent tank. Through this lift pipe, the reagents flow into the top of the cone and are intimately mixed with the raw water. Flowing at a constantly decreasing rate on account of the constantly increasing diameter of the channel, the water passes to the bottom of the cone, turns and flows upward still at a constantly decreasing rate, the precipitate falling away as it moves. The water then passes through a filter which removes all traces of any remaining precipitate, and is then discharged from the top of the softener.

The precipitate, which consists of the impurities of the water combined with the softening chemicals, falls to the bottom of the main tank from which it is discharged through a sludge pipe.

Feed Water Heaters as Purifiers

To some extent, the open type of feed water heater acts as a purifier.

The carbonates of lime and magnesia are held in solution in fresh water by an excess of carbon dioxide and are completely precipitated by boiling. At ordinary temperatures, carbonate of lime is soluble in approximately 20,000 times its volume of water; at 212 deg. F., it is slightly soluble; and at 290 deg. F., it is insoluble, while sulphate of lime is much more soluble in cold than in hot water, and is completely precipitated at 290 deg. F. It will thus be seen that a feed water heater may be used to remove part or all of the lime, depending upon the temperature to which the water is raised and the time allowed for the precipitation to take place.

In the Sorge-Cochrane water softening system, the water first passes through a flow-controlling regulating valve to the water distributing box of the heating compartment, which in construction is identical to the ordinary Cochrane open feed-water heater. From the distributing box, the water overflows upon inclined trays, coming into intimate contact with the exhaust steam as it runs over the trays and falls from one to another. As the water falls from the last tray, it is brought into intimate contact with the chemical reagent, both passing together through a vertical downtake pipe and inverted cone to the bottom of the chemical reaction and sediment chambers, turns and again rises. Before passing out, however, it is forced through a filter bed consisting of wood wool.

The control of the raw water is secured by a float on the delivery side of the filter, communicating through levers and rods with the cold water valve in the raw water supply pipe, the operation of the apparatus being automatic, only enough raw water being admitted as is necessary together with the condensed steam to make up the amount of water required by the boiler feed pump.

The essential parts of the Vater continuous water purifying system consist of a mixing tank, solution tank, heating chamber, settling chamber, filter bed and necessary accessories. Soda ash is dissolved with warm water in the mixing tank from which it is drawn to the solution tank below. The chemical pumps are operated by means of systems of proportioning levers from the piston rod of the main boiler feed pumps by means of which arrangement any desired proportion of chemical to the raw water used may be obtained.

Cold water entering the heater through an automatic valve and inlet pipe is mixed with the weak chemical solution before entering the heater and is discharged into a long trough with serrated edges. Overflowing from this trough, the water is sprayed into a series of pans which divert it back and forth through the heating chamber, thus heating it to a high degree and causing it to deposit all scale-forming materials held in solution.

From the lower tray, the water is discharged into a funnel-shaped downtake and is drawn to the settling chamber below the filter bed. Here the precipitates and

sediment are deposited at the bottom of the settling chamber and may be drawn off through the blowoff shown at the bottom, where also a wash water pipe is provided.

The water passes upward through the filter bed, which is held in position by screen plates keeping a uniform thickness of filtering material. After passing through the filter bed, the water flows to the back of the heater and is drawn off at the bottom to the boilers through the feed pumps.

Exhaust steam enters the heater through the oil separator, which removes the entrained oil and condensed steam and passes into the heating chamber and out at the exhaust outlet near the front.

Doors are provided for removing the trays and filtering material and allow ready access to the interior of the heater. Little scale matter collects on the pans, as they are shallow and set at such an angle that the water flows rapidly over them, allowing only sufficient time for the water to become heated, the precipitation taking place in the settling chamber.

Boiler Treatments

Graphite, as a remedy for boiler scale, does its work by a mechanical process, without chemical effect on either the scale or the boiler metal. It is stated to have a mechanical affinity for iron and for this reason is a metal preservative protecting the surface of the metal from anything tending to cause a chemical action. While an amount of graphite depending on the horsepower rating of the boiler may be placed therein after the boiler has been cleaned and previous to placing it in service again, it is advisable to feed it continuously by some form of feeder, placed on the suction side of the pump, causing the graphite to pass through it, thus at the same time lubricating the valves and cylinders of the pump and tending to preserve the packing and gaskets.

From an extended use of graphite, it has been found that all grades of it do not act alike. While all graphite will readily remove scale, it has been found that graphite obtained from some mines has a destructive effect on not only the boiler metal but all other metal with which it comes in contact, such as feed lines and feed pump cylinders and pistons.

Other Methods of Scale Removal and Prevention

Another preventive used regardless of the boiler water, is Perolin, which is in the form of a thick liquid and is recommended to be fed into the boiler once each day of 12 hr. in a dose based on the heating surface of the boiler. Having a great affinity for the boiler metal, it is immediately attracted to it and by establishing a heat conducting and yet preservative film, it is claimed to prevent all new scale formation taking place. It is further said that starting at a temperature of 180 deg. F., this substance expands under the action of heat until, at the average temperature of steam, it reaches an expansion of 25 times its volume when cold. It is through this action that it removes the coating of scale from the metal.

Another substance used to prevent the formation of scale in boilers, is Permutit, the chemistry of which is not yet entirely clear, the substance being given the rather complex chemical formula $Na_2\ Al_2\ Si_4\ O_2\ 6\ H_2O$. It is a compound having the property of precipitating the calcium and magnesium salts of a water filtering through it, the water coming out clear and containing only a little sodium salt as the result. In due time the Permutit becomes exhausted, but may be regenerated by treating for a few hours with a solution of salt water.

The J-M preservative, a vegetable preparation, acts chemically on the water, removes scale mechanically and at the same time forms a coating on the iron, preventing further formation of scale.

Zinc is often introduced into boilers to prevent corrosion. In the form of blocks, slabs or even as shavings in perforated vessels, it is suspended in the water space with a permanent electrical connection to the shell. By electrolytic action, a feeble but continuous current of hydrogen is generated over the entire surface, the bubbles of hydrogen formed, isolating the metallic surface from the scale-forming substances. If but little of this is present, it is precipitated and reduced to mud while, if there is a considerable amount, regular scale taking the form of the iron surface is produced but, due to intervening bubbles of hydrogen, does not adhere to the shell. Zinc does not always prevent corrosion or scale formation, but in some cases has even aggravated the trouble.

Cleaning of Boilers

TESTS at the Experimental Station of the University of Illinois have recently demonstrated that a 1/16-in. layer of scale entails a waste of from 10 to 12 per cent of the fuel required to generate a given quantity of steam, so it is evident that for economical operation boilers must be kept as clean, both internally and externally, as operating conditions will allow.

Frequency of cleaning boilers is a matter to be decided upon by the man in charge, depending upon the nature of the water supply, the kind of water treatment employed, the grade of fuel used, capacity of the boilers, the load under which they operate and the length of time they are required to be in service. The most economical frequency of cleaning, however, must be determined by the cost and opportunity of cleaning as against loss of fuel, reduced capacity of the boilers and danger of accident resulting from accumulated scale.

As a general statement, it may be said that regardless of the nature of the scale, whether of the hard variety or soft and porous, it is advisable never to allow a deposit greater than ⅛ in. in thickness.

Due to the various qualities of scale, ranging from a white, dense stonelike substance to a dark and porous material, it is impossible to tell, even approximately, what various thicknesses of scale on tubes and sheets have on the economy of fuel. Some authorities claim that the efficiency of the heating surface is reduced in part only by the heat insulating quality of the scale, the remaining loss being due to the rough surface of the scale checking the circulation of the water and the gathering of steam bubbles over the rough surface of the scale, thus preventing contact of the water with the scale, and resulting in the introduction of 2 heat insulating substances between the water and the boiler sheets. Operators of large boilers report finding that a 1/16-in. layer of scale greatly reduces the efficiency of the boiler while being forced.

Instructions for Cleaning

To prepare a boiler for cleaning, the fire should be allowed to burn as low as possible and then pulled out of the furnace, the doors being left slightly open and the damper left wide open in order that the walls may gradually cool. On account of the injurious effects on the plates and seams of the shells and the brickwork of the setting, it is just as bad to cool a boiler off suddenly as it is to fire it up too quickly. After the boiler has become sufficiently cool and no more pressure is indicated by the gage, the blowoff valve may be opened and the water allowed to run out, at the same time keeping the gage cocks and drips to the water column open to allow air to enter and displace the water. If this is not done, a partial vacuum will be formed, causing the water to run out quite slowly. If operating conditions will possibly allow doing so, a boiler should be left for 18 to 36 hr. after being cut off from the line, after which it may be emptied, opened and entered.

By means of a round wire brush or scraper passed through the tubes, they may readily be cleaned of soot, part of which will fall out at the front end, the rest falling onto the floor in the rear of setting.

All ashes remaining on the grates and in the ash pits may then be removed, after which all interior brick-

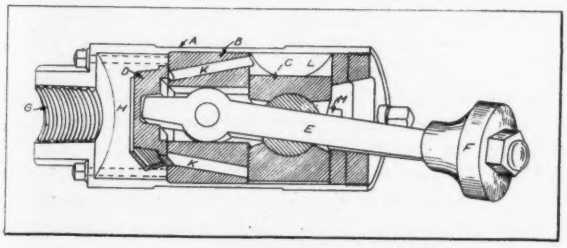


FIG. 1. VIBRATING TUBE CLEANER

work, furnace linings and the shell should be well brushed with flat wire brushes, allowing the soot removed to drop on the floor and grates, from which it is swept.

All manhole and handhole plates may now be removed preparatory to entering the boiler for internal cleaning, and any scale found on these plates may easily be scraped off or, in the case of soft scale, washed off.

Before entering, the shell should be well washed out with a hose and water, allowing the water and all loose scale and sediment to drain out at the blowoff. The boiler may then be entered and by means of a scraper somewhat wider than a putty knife all scale adhering to the interior of the shell may be removed by scraping, except where extremely hard, when it will be necessary to resort to a cold chisel and hammer, carefully going over every part of the interior surface, taking care not to damage the plates in doing so. The method employed must be adapted to construction of the boiler and the accessibility of the different parts for cleaning.

Removing the scale from the tubes is important, and requires suitable tools. Special scrapers may be constructed by any ingenious engineer or a chain may be used by wrapping it around the tube and drawing it back and forth along the tube, and various types of automatic cleaners are manufactured to run through the interior of the tube, rapping or cutting, as the case may be, to dislodge the scale.

Having completed cleaning the upper part of the shell and tubes, attention can now be given to the lower section, where the same procedure may be followed as above. All loose scale on the bottom of the shell can then be scraped off and removed, the smaller particles being afterwards washed out at the blowoff. After washing down and allowing it to drain, the boiler should be inspected, as outlined under Testing of Plates and Joints.

Due to the position of the tubes, scale has little tendency to adhere in water-tube boilers having straight vertical tubes, and after cleaning the drums nothing more than washing the tubes may be necessary.

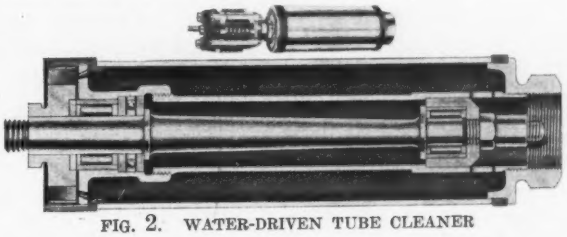


FIG. 2. WATER-DRIVEN TUBE CLEANER

In boilers having horizontal or slightly inclined tubes, and a drum or drums above, the usual procedure in cleaning, after the boiler is cooled down and empty, is to remove the manhole plates in the drums, thoroughly wash out, and remove the handhole plates in the headers, thus giving ready access to all interior parts of the boiler; the drums are treated the same as the shell of a tubular boiler. If containing a hard scale which cannot be washed out, tubes of a water-tube boiler are usually drilled with one of the various forms of tube cleaners to be found on the market, allowing the loose scale to be washed down into the rear header so as to

FIG. 3. WATER-DRIVEN CLEANER SUITABLE FOR BENT TUBES

be easily removed through the blowoff. In drilling inclined boiler tubes, the usual practice is to drill from the front end to the rear, thus not only allowing more room for the man operating the cleaner but also allowing the scale to pass more easily into the rear header. The tube sheets of both front and rear headers may then be scraped, also handhole plates, after which the latter may be replaced and the boiler again thoroughly washed out, allowing all water and loose scale to pass out of the blowoff.

Before replacing handhole and manhole plates on a boiler just cleaned, the gaskets should be examined to see whether they are in proper condition for further use, and if not, use new ones, thus avoiding possible leakage trouble. Many good packings and prepared manhole and handhole gaskets are on the market, and a cheap and reliable form may be made of sheet lead or by pouring molten lead into molds made for the purpose.

In cleaning tubes of boilers consisting of drums connected by bent tubes, it is necessary to enter the drums while operating the drill, but the general procedure in cleaning is similar to that of other types—to wash out thoroughly, then scrape the drums and drill the tubes, after which the boiler is again thoroughly washed.

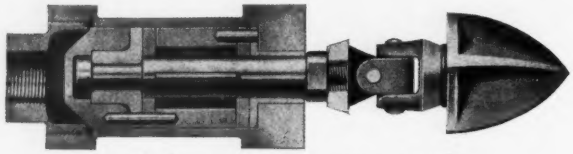


FIG. 4. AIR-DRIVEN TUBE CLEANER

Directions given for the cleaning of the exterior of tubular boilers apply also to water-tube boilers, but in addition to this periodical removal of soot from the heating surface, it is well to blow off daily by means of steam jets the tubes and as much of the shell as is accessible.

Tube Cleaners

These may be divided into 2 general classes, those which loosen the scale by a series of rapid hammer blows and those which cut out the scale by a revolving tool, the former being applicable to either the water or fire-tube boiler, while the revolving cutter is applicable to the water-tube boiler only. Steam, water or compressed air may be used as the motive power; although the latter is preferable, due to being cleaner and safer to operate, it is not often available in quantities necessary.

The power of a tube cleaner depends upon the pressure of the steam, water or air which ordinarily ranges from approximately 35 to 300 lb., depending upon the service to which the cleaner is to be put, 150 lb. water and 80 lb. steam or air being accepted as a fair average.

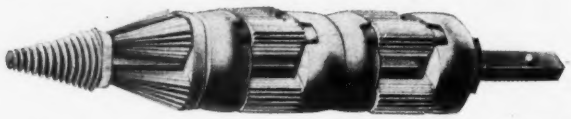


FIG. 5. CLEANER DRIVEN BY EXTERNAL SOURCE OF POWER

Figure 1 shows a tube cleaner of the vibrating type, consisting of a shell A, cylinder B, piston C, valve D, vibrator handle E, and vibrator F. The fluid used passes through nozzle G to chamber H. As the valve D is thrown back and forth, the steam, water or air is admitted alternately through the ports KK to each end of the piston chamber L acting on piston C and giving vibrator F its vibratory motion, the exhaust passing out through N.

The force of the blow exerted by this cleaner is regulated by the volume of the steam, water or air admitted to the piston chamber, not by the pressure. In order to reduce the force of the blow, small plugs are provided so that any number of the passages leading from chamber H to chamber L may be shut off.

Figure 2 is a water-driven tube cleaner having a turbine wheel with blades or buckets cut from solid bronze, smoothly finished and mounted at the end of a steel shaft revolving on roller bearings. Water, entering at the right end, passes through the outer casing of the handle until it reaches the nozzles at the front end; passing through these it strikes the buckets of the turbine, causing them to revolve. The front end of the turbine shaft is threaded to accommodate various styles of cutter heads used for different kinds and thicknesses of scale.

Another water-driven cleaner, Fig. 3, consists of a short handle containing a water motor to the shaft of which various types of cutters or drills may be attached, by means of a universal joint, allowing it to be used in tubes bent to a small radius. The cutting tool consists of a hub screwed over the turbine shaft and having attached short arms, the ends of which are provided with small cutter wheels. As the turbine rotates, the cutters revolve and are forced outward by centrifugal force, thus cutting into the scale.

Figure 4 shows a tube cleaner, with air motor driving the usual form of cutters or drills. The motor consists of an outer casing containing a removable steel cylinder in which revolves an eccentrically mounted shaft containing a longitudinal slot, in which a pair of semi-balanced blades reciprocate. Air or steam is admitted to the cylinder through longitudinal ports in the walls thereof, which in turn communicate with the cylinder at different points throughout its length, producing uniform pressure on the blades. As the blades are mounted in the slot in the shaft, this pressure in them causes the shaft to revolve, thereby driving the cutting head.

Mechanical tube cleaners, Fig. 5, are driven by some external source of power, such as a gas or steam engine, water, air or electric motor, and consist of a cleaner head, shafting of required length, sleeve for centering cleaner head in tube to be cleaned, pulley for belt drive, handle for controlling cleaner and turn buckles for holding and adjusting cleaner in tube.

The head of this cleaner consists of a screw point, revolving cone cutters and revolving cylindrical steel-disk cutters centered on a shaft of the same material, each cutter revolving on a steel pin independently of the others.

When applied to a scaled tube, the screw point first bores into the scale, next the cone cutters loosen the heavy deposit, which is washed away by a stream of water, after which the straight cutters polish the tubes.

Removal of Soot

WHEN it is realized that the insulating value of soot is about 5 times that of asbestos, the desirability of keeping the heating surfaces of boilers free from soot can readily be appreciated. The principal cause of soot is that the volatile gases come in contact with the heating surfaces of the boiler before they have completed their combustion, and precipitate the uncombined carbon which adheres as soot to the heating surface. Bituminous coal, which is high in volatile matter, will, as a rule, cause a greater accumulation of soot upon the heating surface, than will anthracite. The condition of the tube surfaces is also a factor, for if the tube is kept smooth the particles of soot precipitated will be carried through to the stack without finding a lodging

place. Another factor is the speed of the gases through the setting, as a high velocity will tend to carry the soot along with the current of gases.

Excessive accumulation of soot is quite certain evidence that the combustion of the fuel is not what it should be, and furnace conditions should be examined carefully.

To illustrate the value of keeping the tubes clean, in some extreme cases it has been observed that the temperature of the flue gas after the use of a soot blower was 100 deg. less than it was just previous to the use of the apparatus. It may also be stated that a decrease of 16 to 20 deg. in the temperature of the flue gas will cause an increase in the efficiency of the boiler of 1 per cent. Not only does the soot cut down the ability of the boilers to absorb heat from the gases, but the draft loss through the setting is increased considerably, thus impairing the operation of the furnace.

To keep the heating surfaces free from soot during the operation of a boiler, some form of soot blower is the most convenient means, the frequency of its use depending upon the rapidity with which the soot accumulates on the surfaces. These devices consist of means by which a jet either of steam or air may be played upon the surface in such a way as to remove all loose particles which have accumulated. While it is quite generally conceded that compressed air will cut the soot from the surfaces more effectively, steam is more frequently used, owing to the fact that it is always available, does not have a chilling effect upon the tubes, which will cause unequal strains upon the boiler, nor cut down the steam generating capacity during the time the flue blower is being used.

In many plants, hand blowers are still employed, these consisting of a steam tube of proper size to enter the setting or boiler flues, perforated at the end or provided with some form of steam nozzle and attached to a flexible steam hose at the other. To use these blowers it is necessary to open up the doors in order to insert the tube, and in some cases the loss due to cold air entering the gas passages is considerable because the door must be opened several minutes in order to allow thorough cleaning of the tubes. Blowing soot by means of hand blowers is a laborious and disagreeable job, and for this reason, as well as because it takes considerable time and causes some loss in the capacity of the boiler, where this method is employed the frequency of blowing the tubes is seldom more than 2 or 3 times a week.

There are, however, on the market, a number of types of mechanical flue blowers which are adapted to all kinds of boilers. The steam nozzles are located in such positions that the jets of steam will strike all parts of the heating surface where soot is likely to accumulate. Almost without exception these blowers employ steam, but in some instances compressed air may be used to good advantage. The operation of these blowers consists in opening up the steam valve and in some cases working a hand wheel, which causes the jets of steam to travel over the ends of the flues or over different sections of water tubes.

The frequency with which these are used depends upon the accumulation of soot and ranges from every 3 hr. in some plants to twice a day in others. A guide employed in some plants is a thermometer in the boiler breeching showing the temperature of the flue gas. When the temperature has reached a certain maximum, depending upon the equipment of the plant and the load carried, the fireman is directed to blow the tubes. The time required for operating these blowers also varies greatly with the type of boiler, condition of the tubes and fuel used, ranging from 30 sec. in some cases up to 8 min. in others.

All mechanical flue blowers are so arranged that it is unnecessary to open any part of the boiler setting in order to clean the flues, and this method of keeping the surfaces in good condition while the boiler is in operation is quite effective.

On nearly all heating surfaces, there is, however, likely to be a deposit of scale, corroded metal, or even incrusted soot, caused by fine particles of dust carried from the fuel into the tubes, where they settle and adhere to the surface. Corrosion may be caused by the constituents of the products of combustion or due to the sweating of the boiler when it is heated too rapidly upon first starting up. To be on the safe side, therefore, it is the custom in most plants to run scrapers through the tubes in return tubular or vertical fire-tube boilers and to scrape the heating surfaces and outsides of tubes in water-tube boilers whenever the boiler is taken out of service, which varies in different plants from every 3 weeks to 6 months, according to the prevailing conditions. An effective method of cleaning the surfaces which have previously been scraped is to turn a hose stream, carrying a good water pressure, upon them.

Handling Ashes

WHILE the exacting work in a boiler room is to secure proper combustion of the fuel, the importance of taking care of the ashes in the most convenient and economical manner should not be overlooked. In most plants where hand-fired grates are employed, the ashpit is not of large size, and the refuse must be pulled through the front door where it is either loaded upon wheelbarrows or industrial cars and taken outside the plant.

The frequency with which the ashes should be removed from the pit depends upon the rate of combustion and quality of coal. In most plants it is customary to clean out the ashpit after each cleaning of the fire. The detrimental effect of an accumulation of ashes under the grate is that the air supply to the burning fuel is likely to be cut down, particularly at the rear of the grate, and owing to lack of air the heat of the furnace travels down into the grate bars, causing them to warp or burn out quicker than they should. A good scheme which is employed in many plants is to keep a small amount of water in the ashpit which not only keeps fine particles of ash from going up into the fuel bed, but also has a tendency to soften the clinker, due to steam rising from the water.

In the operation of chain grate and gravity stokers, as previously mentioned, there is likely to be more or less fine, unburned coal dropped through the grate at

the front part of the furnace, which, in many plants, is caught in a pan, raked to the front and shoveled into the coal hopper which feeds the stoker. A more convenient method, however, is to provide a separate hopper for this unburned coal where it may accumulate and be discharged into the coal conveyor which delivers it to the coal bunker. Ashes and clinkers are caught at the rear of the furnace by a hopper beneath the boiler-room floor, this hopper being usually built as a part of the boiler foundation, of metal or reinforced concrete and having a capacity sufficient to carry the ashes for a full day's run of the boiler.

Where gravity underfeed stokers are used, but one hopper is necessary to take care of the discharge from the furnace as there is no leakage of unburned coal through the grates.

In either of the above cases, the ash hopper discharges to the conveying system, whatever that may be. In some plants wheelbarrows are used to carry the ashes from the basement to the ash dump, while in other cases industrial cars or even wagons driven into the basements are used to perform this service. One of the most efficient methods, however, of taking care of the ashes, is a bucket conveyor which elevates them from the basement to a bin over the railway track where an accumulation of a carload or more may be stored and delivered by gravity to the cars.

Another method of handling ashes is by means of the vacuum system, consisting of piping leading from the boilers to a bin in which a vacuum is maintained during the operation of the conveyor by means of an air pump. All openings to the piping are carefully sealed, except those through which the ashes are being discharged from the hopper under the boiler, and the current of air into the ash bin carries with it the refuse from the boiler.

Another system of ash handling is by means of a steam jet which works on the principle of the ejector, delivering the ashes from the hopper beneath the furnace to the storage bin, wherever this may be located.

Back of the bridge wall in most boiler settings is a space where soot and fine ashes carried over from the furnace accumulate during the operation of the boiler. The amount of this accumulation depends largely upon the grade of coal used, but this space should be cleaned out every time the boiler is down for cleaning or repairs. One of the most convenient arrangements for taking care of this refuse is a hopper which will discharge into the ash conveying system.

In other plants the floor back of the bridge wall is flat, but a chute covered with a metal plate is provided through which the refuse may be pushed to the ash conveying system. Another method of cleaning out this chamber is to open a hole through the bridge wall and push the soot into the ash pit; the most common process, however, is to scrape the soot through a door in the side of the setting and carry it away in wheelbarrows.

The nature of the accumulation back of the bridge wall depends, as previously stated, upon the character of the coal used in the furnace. In some cases it has the appearance of sand, while in others it is almost pure carbon. In the latter case it is the practice in some plants to mix it with coal and burn it in the furnaces.

Testing Plates and Joints

ON account of continual deterioration, it is necessary that steam boilers be thoroughly inspected both internally and externally at regular periods. Defects are liable to develop in a supposedly perfect vessel, and the natural wear, the effects of scale and deposit and the silent inroads of corrosion are always at work undermining its strength and destroying its efficiency.

An internal inspection consists of an examination of all internal and external parts of a boiler, while it is out of service, empty and open; an external examination consists of trying the safety valve, to see that it works freely, and is not overloaded, examining the water column connections, trying the gage cocks, blowing the water out of the column and noting the time required for it to return to its former level, looking at the fire sheet and the first girth seam, blowoff pipe and elbow through soot door, inspecting feed and blowoff connections and valves, while the boiler is under working pressure.

Frequency of inspection depends upon local conditions, the quality of the feed water used and care bestowed on the boiler generally governing. If the feed water is known to contain any corrosive elements, or is mixed with grease, it will require more frequent inspection than when using a water that contains only scale forming ingredients.

An experienced inspector usually determines the condition of the various parts of a boiler by slightly tapping them with a hammer. Supplied with some form of portable light sufficiently bright to see properly, the boiler may be entered through the top manhole, noting, in passing, the condition of the manhole flange. All braces and staybolts should be sounded with the hammer at the same time carefully examining them, as, although they may ring true and clear, it is possible that they may be in poor condition. Being satisfied that all are secure and free from corrosion, particular attention should be given the shell, carefully examining the sheet just inside the inner rivet line along the longitudinal seam, occasionally scraping the plate with the sharp edge of the hammer or a cold chisel for any evidence of a fracture. The heads of the shell and all visible parts of the tubes can then be examined, noting the thickness and quantity of scale and deposit, the nature, extent and location of any corrosion that may be present and, at the same time, the position and condition of the feed line, the steam and the safety valve outlets.

Leaving the shell, external inspection may be made of all seams, heads, safety valve and water column connections for signs of corrosion, leakage or other defects.

Re-entering the boiler through the lower manhole and passing toward the rear, examine the extent and consistency of scale on the lower sheet and tubes, also the girth seams; sound rivets and braces, and carefully note the amount of scale between tubes and condition of blowoff connection.

In the case of a water-tube boiler, the same internal examination is necessary, as the drums, if lap riveted are subject to the same possible failures at the longitudinal seams as the shells of horizontal tubular boilers. In making the internal inspection, the shell plates, tubes,

header, water legs, staybolts and mud drums, according to the type of boiler, should be gone over.

Hydraulic Tests

In the absence of, or in some cases in addition to the above, many operators subject boilers in their charge to a hydraulic test. After the boiler is cleaned and all handholes and manholes securely in place, the blowoff valve, the safety valve and water column connections closed, the boiler is filled with water. After which the feed pump is kept in operation, allowing the pressure to increase gradually until, according to the indication of the steam gage, a pressure 1½ times that under which the boiler usually operates, is reached. The pump is then stopped and a careful examination of seams, joints and all flanged, expanded or riveted connections made.

Repairing Boilers

As a rule, boiler repairs should be made by an expert boiler maker, but there are certain repairs which the engineer can make with good results and he should be thoroughly familiar with the processes employed by the boiler makers themselves in order that he may know when the work has been properly done.

Leaking seams or rivets is one of the most common defects in boilers, and may be overcome in most cases by calking. This is a simple process, but one which must be done with some care in order to avoid injuring the boiler plates and rivets. It consists of forcing down the edges of the plate and the rivet heads so as to give a firm bearing, and prevent the escape of steam or water

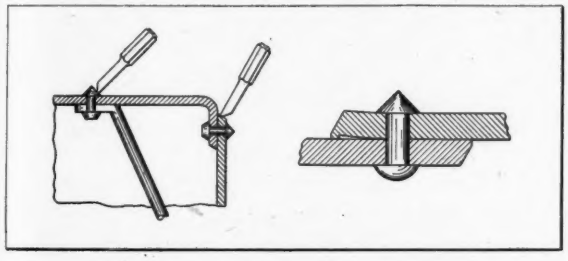


FIG. 1. USING THE CALKING TOOL AND RESULTS OF OVER CALKING

past them. The danger of over-calking is, first, in splitting the edge of the plate or the head of the rivet, second, in driving an edge of the plate so hard as to open the rivets between the plates. Calking should always be done with a round nosed tool, which is not liable to cause cutting on the under plate, that might result in a crack. The work needs some skill and experience as a heavy blow is much more effective than a light one, yet too heavy a blow is likely to produce injury to the plate.

Cracks in the boiler shell or tube sheet are usually caused by expansion strains, but may result from improper calking or excessive corrosion near the joints. If the crack is not extensive, it may be remedied by putting on a patch. This method of repair, however, is considered by many as a make-shift. The safest method of repairing is, of course, to replace the plate which is damaged, or, in some cases all plates may be cut off, shortening the length of the boiler a few inches, thus cutting down the expense of the repair without material loss to the capacity of the boiler and making it as safe as a new sheet.

To replace a sheet in the shell of any drum it is necessary first to cut the heads off the rivets in the joints which hold the sheet in place. The rivets can

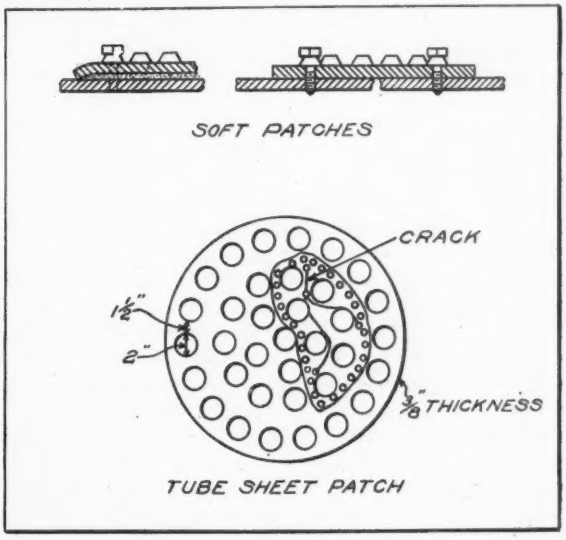


FIG. 2. BOILER PATCHES

then be punched out, the outer butt straps removed and the damaged plate taken out. The next step is to see that the new sheet is rolled to the proper diameter and fits closely in the space where the old sheet was located. After this is done the butt straps may be bolted into place and the rivet holes spotted on the new sheet;

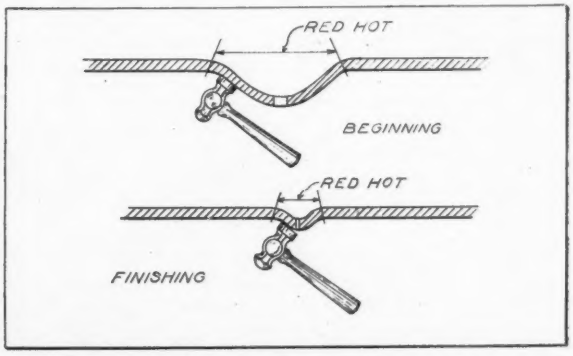


FIG. 3. HAMMERING BAG BACK INTO PLACE

then remove the plate to a drill and drill the holes to 1/16 or 1/32 in. less in diameter than those in the butt strap. The sheet is then put in place, being securely held by bolts and the holes reamed to the proper diameter, after which the joint is riveted and calked in compliance with best practice.

To replace a tube sheet requires considerable skill and practice, and in nearly all cases it is advisable to secure the services of a boiler maker for this work. Putting on patches is another job which requires an expert boiler maker, for in nearly every case of defective

parts there are new conditions to meet which require good judgment. There are 2 kinds of patches which may be employed, the choice depending upon the location of the defect, time available for making the repair, and the tools which are at hand. These patches are known as the hard and the soft patch, the first being employed for permanent repairs and in any case is that which should be recommended except where conditions prohibit. The soft patch is more or less of a temporary affair, but may be used in locations where riveting cannot be done without great inconvenience. It consists of a suitable piece of boiler plate cut large enough to cover the defect, and allow a wide margin for the reception of the patch bolts which are machined and usually provided with a special form of head as shown in the sketch.

After the patch has been bent to the proper shape over an anvil or by some other means, so as to conform as nearly as possible to the contour of the boiler shell, the bolt holes are drilled and the patch pressed against the shell to permit locating the holes in the plate. When these have been drilled and tapped, the patch is put in place with cement or red lead putty between the shell and the patch, or a gasket may be used for this purpose. In some cases, the surface of the patch is dished slightly so that the filling will not be squeezed out when

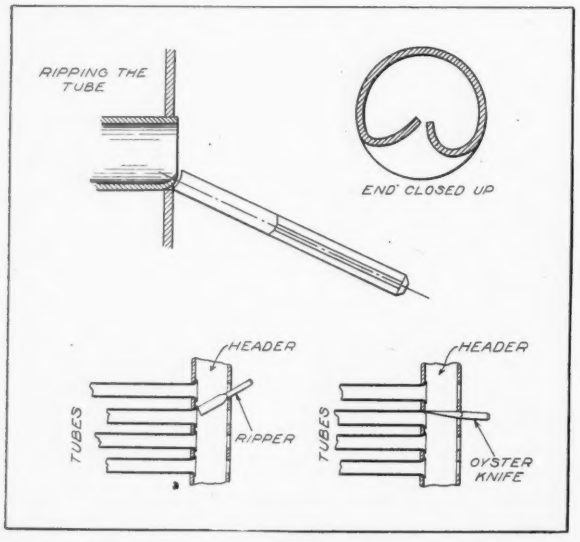


FIG. 4. CLOSING UP ENDS BEFORE REMOVING TUBES

the bolts are screwed tight. After the bolts are screwed home, the square portion of the heads is cut off, giving the repair the appearance of a hard patch. Patches put on in this way should be allowed to stand from 3 to 5 hours before water is put in the boiler and pressure raised.

A hard patch is formed the same as a soft patch, but the plate is cut away under the patch, leaving, of course, sufficient material for the rivets to hold, rivets are used in place of bolts, no cement or gaskets are used and the edges of the patch and plate are calked to give a tight joint. Hard patches must be employed in all places exposed to fires or hot gases, and are preferable to soft patches in any case. Where the patch is made

there is a ledge in the surface of a depth equal to the thickness of the plate, and special care should be taken to keep the boiler clean so that the corner will not become filled with an accumulation of sediment while the rest of the heating surface is clean and safe.

To mend a crack in the tube sheet of a boiler is not an easy job owing to the fact that the rivets must be so located as not to weaken the plate and the shape of the patch is irregular owing to the presence of tubes. The accompanying sketch shows how it may be done in a manner acceptable in Massachusetts. Drill small holes and put in screws at the ends of the cracks to keep them from spreading, then place the patch over the crack, having first cut holes which go over the ends of the fire tubes. If the surface on top of the boiler is rough, a coating of lead will be needed before the patch can be put on with rivets which are pitched equally between the flues. Thimbles or ferrules are then expanded or

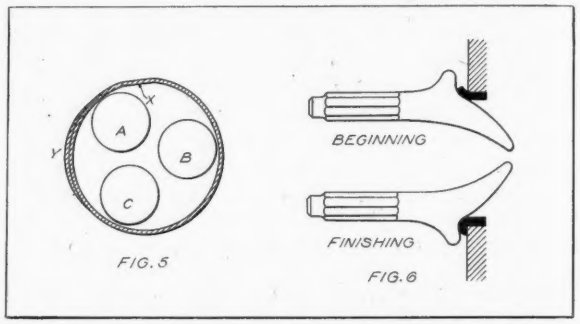


FIG. 5. END OF TUBE IN IRREGULAR SEAT
FIG. 6. TOOLS AND METHOD OF BEADING

beaded in the tube ends to make them tight, or if the tubes are taken out they can be expanded into both head and patch.

In cases where the heads are burned or blistered the same kind of a repair may be made instead of putting in a new tube sheet, but in this case the tubes should be expanded into the patch which has just been put into place.

In the operation of return-tubular boilers it is not uncommon, particularly when the boiler is being forced, to have the shell bag above the grate or bridge wall, caused usually by the accumulation of scale or oil on the inside of the boiler. If the plate does not let go at the time the bag occurs, it is practical, in many cases, to drive the shell back into place, preferably heating the metal with a torch to a red heat, then hammering the plate back into place. The hammering should first be done on the outside part of the bag, gradually working toward the point of the bag and going over the surface repeatedly until the entire metal is back into its proper place. Do not try to reduce the bulge in once going over. Before this repair is made, however, a hole should be drilled through the point of the bag to see that the thickness of the metal is such that it will stand driving back to its original position; this hole can be stopped up with a rivet. In case the bag cannot be driven back, the only remedy is a patch or a new sheet.

When a boiler tube becomes defective, it is usually considered best to remove the tube and replace it with

a new one, except when a leak occurs between the end of the tube and the tube sheet. The method of procedure in removing a tube depends largely upon the location of the tube in the boiler and the type of boiler. If the defective tube is in a return-tubular boiler and so located that it may be removed through the lower manhole, the proper method is to cut the tube off at one end just inside the head with a bent chisel or a tool known as a ripper. At the other end the bead is cut and the tube bent in so as to allow the tube to be drawn inside the boiler and lowered to the manhole, where it is removed.

If the tube is so located that it cannot be taken out at the manhole, it must come out through the tube hole. This is a difficult job, owing to the fact that the tube is usually covered with more or less hard scale, increasing its diameter so that it will not slip readily through the hole in the tube sheet. In such a case it is advisable to run a tube cleaner through the tube, knocking off the scale as much as is possible before the tube is cut. With both ends of the tube closed in, the tube may be started by driving with a hard wood block and sledge, at the same time drawing by means of chain tackle.

After the old tube has been removed the new tube is slipped in, which is usually not a difficult job as it is smooth and of proper diameter. Before the tube is put into place, however, the seat in the tube sheet should be cleaned and trued up, particularly if damaged during the removal of the old tube. In some fire-tube boilers the tube hole is larger than the tube, and a copper ferrule is used to fill the space, being rolled into place before the tube is inserted. When the tube has been put in its proper position it is rolled or expanded against the tube sheet and beaded over so as to prevent leakage as well as to support the tube sheet against the pressure inside the boiler. If it is necessary to expand the end of the tube considerably to make it fit the hole in the tube sheet, it may be advisable to anneal the ends of the tube before it is inserted in the boiler. This will prevent the tube from splitting when the roller is working. Tubes placed in fire-tube boilers should extend beyond the tube sheet about ⅜ in. in order to allow for beading. If they extend through the sheet further than this, the ends are liable to crack when the end is being beaded over.

Expanding of the tube is usually done with 1 of 2 types of tools, known as the prosser and the roller. The former does its work by means of a turned taper wedge driven into the center of a block of the proper shape, which is made up of a number of wedge sections held together by a spring. Driving in the pin forces these out to a greater diameter, thus pressing the metal of the tube tightly against the tube sheet. The roller expander consists of a frame carrying 3 steel rollers which are forced against the tube by a tapered plug. The plug is tapered slightly to force the rolls out against the tube and the expander is turned to roll the tube out against the sheet.

To use the roller correctly, instead of rolling around continuously all the time, turn until the roller sticks at some spot and, if forced, will roll easily again for a short distance. This sticking is caused by a thick place in the tube or the hole not being round. The latter may result from the ignorance of the operator. The illustration shows clearly why the roller would stick. To make the tube tight when the roller sticks, turn it back and roll back and forth, letting the roller A, for instance, come up to the bump on one side of X and roller B come up on the other side. One must go by the feel and quit when he gets it right for, if continued too far, it will tend to lessen the thickness of the tube at point X.

If there is a low place in the sheet, as at Y, roll around until it is tight everywhere else. In this the operator must be guided by the sense of touch, as the expander will turn easier as one of the rollers passes over the low place in the sheet. To tighten the tube at this point, place the rollers at this easy place and tap on the pin and roll back and forth, letting the roller come up to the shoulder on either side. One can tell that there is such a place, but often cannot tell which roller is doing the work; and again this easy place might be a thin place in the tube. Of course, these difficulties are not always encountered.

After the end of the tube has been thoroughly expanded, it is beaded over the front of the tube sheet, 2 forms of tool being used for this purpose, for starting and for finishing, the operation with each one being plainly shown in the illustration, Fig. 6.

Water-tube boilers are built in so many different styles and shapes that no general rule for removing the tubes can be given. In the horizontal type the tubes most frequently needing renewal are in the bottom row, and these may be removed by cutting near the ends and dropping into the furnace. For a tube above the first row, it may be necessary to remove all tubes below it, owing to the fact that water tubes are apt to be blistered or bagged to such an extent that they cannot be pulled through the headers, although this is the most economical way if it can be done.

Tubes in water-tube boilers are not beaded, but are burred or flared out at the ends by first expanding the tube in the sheet, then pulling the rolls out so that the end projecting beyond the header from ¼ to ¾ in. will be expanded to a diameter of about ¼ in. greater than the tube.

As a precaution, after repairs have been made to any boiler, and before firing up, the boiler should be closed, a hydraulic pressure at least equal to the working pressure put on, and the repair examined for leakage.

Repair of Brickwork

AS explained elsewhere, infiltration of air through boiler settings is conducive to such great losses that it is of utmost importance that no leaks exist. Various methods are employed to determine the location of air leaks in the setting, the commonest consisting of closing the damper while the boiler is working under a comparatively heavy load and noting the points from which smoke issues. Knowing the approximate location of the leak or leaks, the exact point may be found, with the damper open, by exploring the settings at this place with a tallow candle or a torch, when the flame of the candle or torch will be drawn in, thus indicating the leak.

Another method frequently used is that of entering the setting as soon as sufficiently cool and while the interior walls are still covered with soot. Leaks of

any consequence caused by cracks in the settings will readily be recognized by the absence of soot in close proximity thereto, which may readily be stopped by filling with asbestos or pointing the brickwork.

Prevention of Clinker on Fire Brick

To some extent, clinker may be prevented from adhering to the furnace walls by using a fire brick of the purest quality, the mixture containing as little iron as possible, so that the ash or clinker will not adhere to it and by not banking the coal too close to the lining. Some authorities recommend giving the linings of the furnace

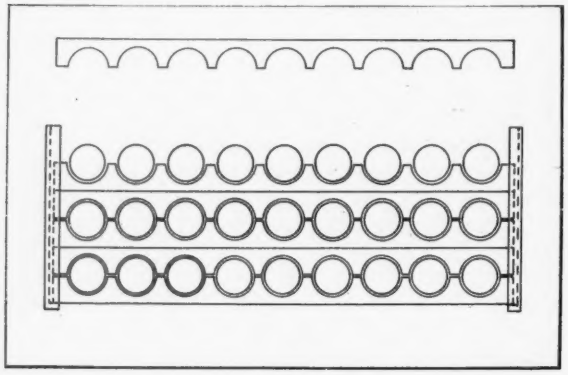


FIG. 1. FORM OF VERTICAL BAFFLE TILE AND METHOD OF PLACING AROUND TUBES WITH CHANNEL IRONS AT ENDS

frequent coatings of white wash made of lime. Various fire bricks such as Bauxite are on the market, the manufacturers of which, the Harbison-Walker Refractories Co., of Pittsburgh, Pa., claim that it will successfully resist the adhesion of any clinker. The Philadelphia

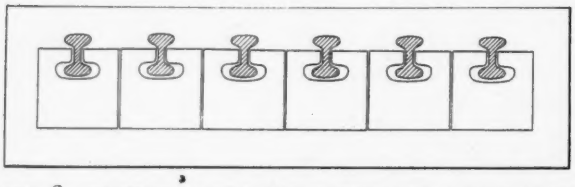


FIG. 2. SECTION OF TILE AND HANGER FOR A FLAT ARCH

Fire Brick Works, of Philadelphia, Pa., recommends the use of its Holdfast concrete fire cement, which under high heat welds together with the brick, forming one solid mass to which the clinker will not readily adhere.

After the clinker has once formed, however, the best means of removal is by the use of chisel bars at such intervals as to prevent an amalgamation of the elements of the clinker with those of the fire brick.

Ignition Arch Renewal

Ignition arch repairs or renewals usually require considerable time and labor and should be made by a mason experienced in this line of work. Various methods of construction and support of ignition arches are employed, depending on the type of boiler and furnace in question. Ordinarily, an arch is built up of common fire brick, or in some cases is constructed of blocks of standard size and shape made of some highly refractory material, as explained under Fire Brick. Some forms of mechanical stokers require for their successful operation the use of a flat arch, in which case it is necessary to provide arch blocks with slots of such shape that they may be hung on modified I beams suspended above the furnace. Another form of arch or furnace roof used in some water-tube boiler furnaces is made up of blocks of refractory material placed around and supported by the lower row of tubes, this form of construction being fully explained with detailed illustrations on previous pages.

Due to the continued action of intense heat, the best grades of fire brick will, at some time, become partially or wholly disintegrated and as a consequence parts of the arch will fail, varying from a single brick dropping out to the falling of the entire arch, requiring repairs to be made accordingly. If it is but the dropping of a single or a few bricks, these may easily and quickly be replaced the next time the boiler is shut down. If, however, a part or the entire arch fails, the boiler must be shut down at once. Under these conditions, after having allowed the furnace to cool and removed the coal and ashes from the grates, all remaining parts of the arch which show the slightest sign of weakness should be removed. Then in the case of an ordinary fire brick arch, it will be necessary to build up a wooden form conforming to the general lines of the arch over which it is to be built. This, however, is unnecessary when using special formed blocks, as they are obtainable in such sizes and forms that they may readily and easily be built up into the desired form of arch.

When a flat arch, the blocks of which are hung on I beams running parallel to the furnace is used, a minimum amount of time and labor is required to make repairs. The damaged block or blocks may be removed by first sliding out those in back and then taking out the damaged members. The first ones removed, if in good condition, may then be put back, not forgetting to add new blocks to replace those just discarded.

By studying the form of the blocks used to build up a furnace roof under and around the lower row of tubes of a water-tube boiler, as shown on pages 42-51, it is readily seen how easy it is to replace these in case such becomes necessary.

Baffle Repairs

In order to prevent the short-circuiting of the furnace gases with the attendant loss in efficiency, it is important that the baffles be kept in good condition, this requiring eternal vigilance on the part of the operator.

In time, baffling, like other parts of the boiler setting, deteriorates, resulting in the tile falling out and allowing the gases a shorter path of travel. The method employed in repairing fallen baffling depends upon its position, construction, and the material of which it is made. One of the simplest baffles is that used in boilers of the type of the Wickes vertical water-tube, consisting of a single wall and generally built up of standard baffle tiling. If this or any part of it fails and falls, it is necessary to remove all broken and weak appearing sections, well cleaning the joining surfaces upon which the new wall may be built.

In case of the failure of a horizontal baffle in a horizontal water-tube boiler, the old baffle, as before mentioned, must be removed, after which the new blocks may be put in, binding them well with a good cement made of fire clay. In many horizontal water-tube boilers a combination baffle and furnace roof is used, the replacing of which was discussed under Renewal of Ignition Arches. When a vertical baffle falls, a section of which is of the shape shown in the accompanying illustration, renewal may be accomplished by cleaning those parts of the tubes which will be surrounded by the tiling, then building up the baffle, binding the different sections by some good fire clay mortar or cement. The tile used is passed horizontally between a row of tubes to one side of the place in which it is to set. Then by turning it through an angle of 90 deg., the tile will go in place surrounding half of the tubes as shown, the other half of the tubes being surrounded by the opposite tile.

While in some installations, the ends of these tiles have been imbedded in the furnace walls, this method of construction has been found unsatisfactory due to the great amount of labor required to replace such a section of baffles. The ends of the sections may be held together by channels slipped over and cemented to the ends, although even this is not always necessary.

Another form of baffle on the market, consisting of cast-iron plates covered with a layer of asbestos, seldom requires renewal; but when it does, the entire section must be broken out and replaced by a new one. This type of baffle is used where it may lie parallel to the tubes and therefore can easily be slipped in between 2 rows of tubes or in back of or on top of a bank of tubes, depending upon the type of boiler. The plates are held in place by U bolts bolted around the tubes.

When renewing baffles in boilers, with tubes of peculiar shape, it is necessary to build up the baffle tile by tile, carefully following the surface of the tops of the row or rows of tubes.

Repair of Valves and Piping

WHEN we realize that the loss of steam through an orifice ¼ in. in diameter, under a pressure of 100 lb. gage, amounts to about 10 b.hp., the importance of stopping all leaks about a power plant may be fully realized. Yet, it is the exception rather than the rule, to find a power plant which is without steam leaks. It is, however, not always an easy matter to find just where leaks are located, and the proper method of repairing them often entails considerable expense.

To be on the safe side, repairs should never be made upon a boiler, piping or other vessel containing steam while it is under pressure. While it is quite a common practice to treat a small leak with the vessel under pressure, by a few blows with a calking tool or punch, or under like circumstances to set up nuts on header flanges or on the bolts of manhole covers or handhole plates, this practice is exceedingly unsafe and should be absolutely forbidden.

One of the most common locations of a steam leak is through the blowoff valve, since it handles the sludge and sediment which has been precipitated in the boiler which is likely to cause cutting of the valve seat, or sediment may lodge between the seat and disk, preventing the tight closing of the valve. The discharge line from the blowoff, if visible, would show the existence of a leak, but in most plants this is not the arrangement of the piping since the discharge is usually taken to a blowoff basin. In such case, it should be made a matter of routine practice for the fireman to feel the discharge of the blowoff valve occasionally, and if the temperature is high while the boilers are not being blown down this is quite certain evidence that the blowoff valve is leaking.

When this occurs, the valve should be examined at the first opportunity to ascertain the cause of the leak, and make the necessary repairs. It may require only the removal of some scale or sediment; but some part of the valve may be broken or worn to such an extent as to require replacement. Blowoff valves are usually of some special construction which does not permit the regrinding of the valve seat, so that repairs consist, ordinarily, of replacing the parts.

It is not uncommon to see safety valves dribbling a small stream of steam, particularly just below the blowing off pressure. This is usually due to a poorly fitted valve seat, although other parts of the valve may be worn so as to prevent the disk from seating properly. Such a leak can always be seen and the remedy is to renew the parts, or if this cannot be done to advantage, the valve should be replaced with a new one.

A leaking stop valve is probably the most dangerous which exists in a power plant. The great difficulty here is that it cannot be seen nor detected without special examination. If the lead from the boiler to the header is provided with a stop valve, also a check or non-return valve, as is the case in most boiler rooms, a leak through the stop valve when the boiler is out of service will permit the pipe between the stop valve and the check valve to fill with condensation, and when the boiler is put into service, is likely to cause water hammer with attending disastrous results.

Such a leak is also dangerous when a boiler is being repaired or cleaned, by men compelled to get inside the shell of the boiler, as there is no certainty that the valve will hold and suddenly giving way may scald the workmen. To detect such a leak, a drain pipe from the main lead just on the boiler side of the valve is convenient, as any condensation discharged through this pipe while the boiler is out of service is a sure indication that the valve is leaking.

In cases where but one valve is in the lead from the boiler to the main header, when this boiler is filled with water and out of service, a leak in the stop valve will cause steam to enter the cold boiler and condense, thus raising the water level in the boiler.

Such a leak may be caused by imperfect adjustment of the valve seat or disk, but not infrequently is due to strains on the piping system caused by expansion or contraction with variations in temperature. In the former case the remedy is obvious, but in the latter it may be necessary to reconstruct the entire header system of the battery of boilers.

Leaky valve stems are not infrequently seen in power plants, in fact, this is probably the most common location of steam losses in the boiler room. The reason for this is probably that attendants do not consider such leaks dangerous and the repair is neglected.

Valve stems should be packed with as much care as the piston rod on an engine, and in valves of modern construction this work may be done while the valve is under pressure, either closed or fully open. The exact course to follow in doing this job depends almost entirely upon the construction of the valve, but in any case a good grade of packing should be used, which is suitable for the pressure or temperature to which it will be subjected.

Another cause of leaking valve stems is that they may become corroded, due to their remaining in one position for a considerable length of time, or the valve stem may be bent, causing it to push the packing away from itself each time the valve is operated. The remedy here is obviously to put in a new valve stem.

To lengthen the life of the body of the valve, it is modern construction to provide it with some arrangement to regrind the seat or disk automatically so as to maintain a perfect joint, or with renewable disks and seats which are easily replaced in case they become worn through use. To supply this need in valves of older construction, there are on the market a number of reseating tools which perform excellent service, and if properly used will lengthen the life of the valve 3 or 4 times.

Leaky pipe joints are another source of considerable steam waste in the power plant. This may be caused by poor pipe threads or the workmanship of the pipe fitter may not be good. Pipe threads should be smooth and even and cut full depth, but should not extend farther back from the end of the pipe than the pipe is expected to enter the fittings. In many cases an extra turn on the fitting will stop a leak. This, however, is not always the case, and a close examination should be made before tightening up on a fitting which leaks. Leaks may be due to undue strains on the piping, caused by expansion and contraction without proper provision being made in the system. In this case the only remedy is to rearrange the piping, providing expansion joints, loops or offsets. In some plants, it is customary, when remaking a joint, to replace the old gasket almost regardless of its condition. Such practice is likely to cause trouble with leaks and is not to be recommended except in cases where a metallic gasket is used. Cracked flanges may also be the cause of a leak, usually as the result of undue strains upon the piping system.

In closing, again the caution that repairs to the boiler, piping or other parts of the steam system should never be made while steam pressure is on the system.

Testing of Safety Valves

AS the safety valve is the sole reliance to prevent the accumulation of an excess of steam pressure in case of neglect or inattention on the part of the man in charge, it is important to examine its mode of operation carefully. Safety valves are usually provided with a spindle or guide beneath the valve, and if through careless handling this becomes bent, the safety valve may be rendered inoperative, so that, instead of rising at the desired pressure, it will turn sidewise, allowing but a small opening for the escape of steam, and will not reseat properly.

Seats of safety valves should be examined frequently to see that no corrosion has set in, as this will cause them to stick, requiring considerable force to raise them. If a valve properly adjusted is found leaking, an immediate examination should be made for corrosion of seat or guide, and for foreign matter between the valve and its seat. By opening the valve a few times, any substance that may have kept it from its seat will become dislodged. In the case of a lever safety valve the lever may have become bent, causing it to be out of center. Whatever the trouble, the addition of weight or greater spring tension to secure tightness should never be resorted to.

In order to determine whether the valve will operate at the desired pressure, it is advisable to test that the steam gage is correct, then raise the boiler pressure until the valve opens, noting the pressure at which this occurs. It is good practice to do this every time after the boiler has been down for cleaning.

Safety valves should be tried out every time the firemen change shifts, and if any unusual force is required to open them, the trouble should be investigated and remedied at once.

Blowing-Off

DUE to the variation of local conditions, no hard and fast instructions can be given regarding the frequency of blowing down boilers. A blowoff is for the removal of loose scale, sediment, mud and any substances other than water, and as soon as such substances have had an opportunity to accumulate they should at once be blown away. As soon as they are removed, which can be determined by watching the escaping water, the blowoff valve should be closed, as the escape of the hot water and steam is a waste of heat. A good rule to follow in blowing down boilers is to open the valve slowly and when wide open to close it again slowly, thus avoiding any sudden impact due to the pressure of the steam on the valves, branches or headers, and at the same time allowing a sufficient amount of sediment to escape. An exception may, however, be made to this in the case of extremely dirty water when not only should the boiler be blown for longer periods but also more often.

It has been found upon investigation that a wide variation in the frequency of blowing down boilers exists. As the result of recent visits to a great number of power plants, it was discovered that where the water was particularly bad the boilers were blown down once every hour, while in another plant the chief engineer would not allow his boilers to be blown down except when preparing them for cleaning. As might be presumed, the water used in the boilers of this latter plant contained very little dirt or scale forming matter.

FOR HEATING, saturated steam is better than superheated, hence, it is better to make the steam at low pressure than to use high-pressure steam through a reducing valve. Exhaust steam, which is always saturated, is as good as that from a low-pressure boiler. If it is necessary to use reduced steam from a superheater for heating, a spray of water, to reduce from superheat to saturation will make the steam more effective.

Laying Up Boilers

FREQUENTLY in the operation of a power plant, it becomes advisable to lay up one or more boilers during a dull season. When this is done, extreme care should be taken to see that all parts of the boiler are clean, even scrupulously so, inside and out. The water should be let out of the boiler and if any remains it should be mopped up with a sponge or rag. Some engineers dry this moisture out by burning light fuel, such as paper, in the furnace, but this practice is not recommended, as it may cause damage to the plates.

After the water has run out, the manholes at the bottom of the heads should be left open and, for a water-tube boiler, the hand holes at the bottom of the headers in addition to those in the shell; this will allow air to circulate freely through the interior of the boiler and keep it dry. Care should be taken to prevent steam from ashes of another boiler or other moisture from getting into the boiler, as but little moisture is needed to cause corrosion.

Soot or dust will collect and retain moisture much more readily than the clean boiler plate, which is one of the principal reasons for having it removed. Not only should the metal of the boiler be clean, but all parts of the setting, including the furnace.

When the boiler is one of a battery, the draft through setting will soon dry up the moisture on the inside after the manhole and handhole plates are removed. All valves on pipes connected to the shell should be examined to be sure they are tight, and all needed repairs should be made as soon as the boiler is out of service so that it will be in condition to be put back into service without delay, if needed in an emergency.

Manholes and Handholes

NO definite statement can be made relative to the location or number of manholes and handholes as these are factors which vary in each make of boiler. It may, however, be said that every boiler should be provided with sufficient and properly located manholes and handholes so that the boiler may be as easily cleaned and inspected inside as outside.

Tubular boilers usually have one or more manholes in the front tube sheet and another on top, near the rear of the shell. In water-tube boilers, manholes are placed at one end of each drum and handholes are usually placed opposite each tube opening in the front and rear headers. Boilers, such as the Stirling, with tubes expanded into drums, have a manhole at one end of each drum, thus providing for inspection and cleaning of all tubes.

Usually, manholes are elliptical in form and approximately 14 by 16 in. in size, so that the body of the average man may easily pass through. In the majority of cases, handholes are also elliptical in form and have a minor axis equal to the diameter of the tube opposite which they are placed, being ordinarily about 4 by 6 in.

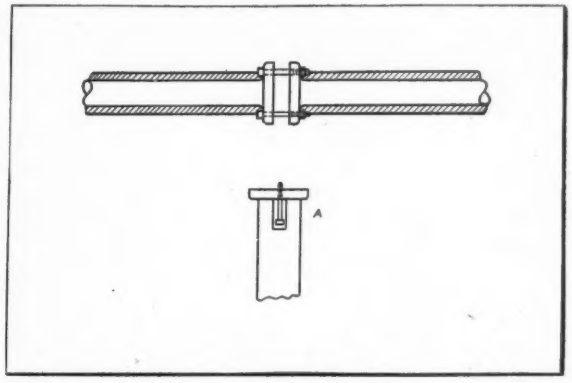
All manholes and handholes are so made that the pressure of the steam keeps their plates, which are of cast iron or steel, in place and, as a further support, handhole plates are held in position by removable bolts and 2 or 3-pronged guards bearing on the outside of the sheet. Manhole plates are generally held in place by 1 or 2 guards and bolts.

Cutting a manhole in a boiler sheet has a tendency to weaken the sheet, and to compensate for this, the opening is surrounded by a reinforcing flange made of either cast iron or steel.

Renewing a Gasket

IN ALMOST all cases where piping is covered with magnesia, and no up-to-date plant is without, it becomes necessary to renew gaskets in the flange fittings and if the covering is removed, in 9 cases out of 10 it is either broken or, if replaced, does not look so well nor so neat as before it was disturbed.

The writer had occasion to renew several gaskets which were leaking, and hit upon the following scheme, which is illustrated in the sketch. Instead of removing



METHOD OF REMOVING PIPE COVERING IN ORDER TO RENEW GASKET

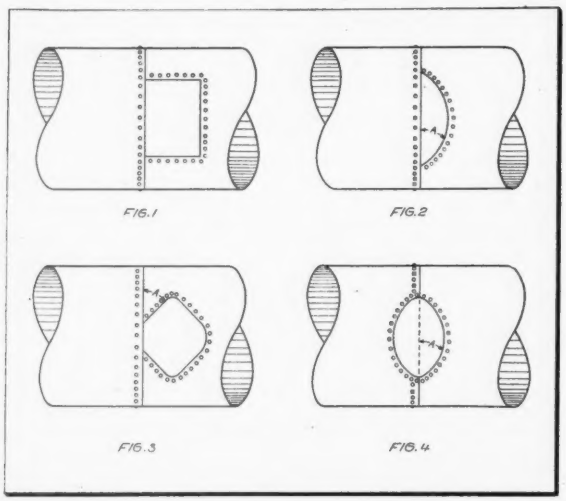
the covering, one band was taken off and with a knife a slot was cut back of bolt as at A in the sketch, in which the bolt can be slid back, the flanges wedged apart, new gasket inserted, the small piece put in place and when rebanded, looks just as if never touched. In the writer's case, only 2 slots were necessary, as a ring gasket was put in instead of a full gasket, and 2 bolts were loosened only enough to allow the gasket to be taken out and another put in. RICHARD E. WEBB.

Boiler Patches

WHEN applied to sheets not in contact with the fire, a soft patch is serviceable and this method of repair is found frequently at the outer corners or below the grates of the firebox of locomotive type boiler. A soft patch applied to a firesheet is, however, an abomination and should an inspector find a boiler repaired in this manner his orders would be, not to cut the pressure, but to remove the soft patch and apply a hard patch. It does not follow from this that a boiler that has been bulged and has a hard patch put on will not have to be cut in pressure. It is more than likely that a cut will be made if the pressure previously allowed has been close to the maximum allowable pressure.

In laying out a patch, it should be designed to give the strongest seam possible under the conditions; the quality of the stock in the patch should be at least as good as that in the boiler and not a piece of tank steel of unknown quality. Its thickness should be equal to that of the boiler shell and for several reasons the patch should be inside the shell. But one row of rivets can be used in a patch on a firesheet, therefore the efficiency of the joint will be low. Now, the joint in a well designed patch is usually a combination of a girth joint and diagonal joint. Sometimes a circular patch is possible, which is the strongest form of patch; but this is confined to small repairs and for our purposes we will consider the forms shown in Figs. 1, 2, 3 and 4.

Figure 1 shows a square patch, a form to be avoided since 2 edges are only single riveted longitudinal seams. Figure 2 illustrates the form commonly met with in boiler work and is generally termed a half moon patch. Figure 3 is known as a diamond patch. It may, in some



cases, approach an ellipse in general form and is then designated by the term its shape would imply. The diamond or elliptical patch may be used to advantage where a large cutout must be made. By drawing in as shown in the sketch it is not necessary to cut so far up on the roundabout and tearing out of the side walls may thus be avoided. Figure 4 is about the same form as Fig. 3. It shows the method used when adjoining courses and the girth seam have been bulged. This patch, like the others, should be inside.

The seams shown in Figs. 2, 3 and 4 are virtually diagonal joints and have an effective efficiency in excess of a longitudinal joint of like proportions. This increase is dependent upon the angle that the edge of the patch makes with the girth seam (angle A in Figs. 2, 3 and 4). The smaller the angle the nearer the diagonal joint approaches a girth seam and consequently the greater its effective efficiency. Before a patch is put on a boiler, it should be laid out either on the boiler shell or at the drawing board and the safe working pressure for the boiler determined in the event of the patch being applied. The process is this: having determined the best cutout that will remove all the defective metal and give the least angle with the girth seam, lay out the seam to be used. This will be single riveted and its efficiency should be calculated in the usual manner for a single riveted lap joint. We now wish to determine the effective efficiency of the joint as a diagonal seam. This can be determined quickly from the table simply by multiplying the efficiency as calculated, by the constant corresponding to the angle formed by the joint in patch and girth seam. Thus, if the greatest angle A in the patch is 42½ deg., and the calculated efficiency of the joint is 52 per cent, the effective efficiency will be $52 \times 1.30 = 67.6$ per cent.

Should 67.6 per cent be in excess of the efficiency of the longitudinal seam of the boiler, no reduction of pressure will be necessary because of the patch. If, on the other hand, this effective efficiency is less than that of the longitudinal seam, it is then necessary to figure the safe working pressure on the strength of the patch, the formula being

$$P = (t \times TS \times E) \div (R \times FS).$$

t = Thickness of plate in inches.
TS = Tensile strength in pounds per square inch.
E = Effective efficiency of diagonal joint.
R = Radius of shell in inches.
FS = Factor of safety.
P = Working pressure.

The efficiency of a single riveted longitudinal seam will range from about 40 to 50 per cent and the effective efficiency of a diagonal seam within the limits of the table will range from 45 to 75 per cent. This is about equal to a longitudinal lap seam double riveted.

A longitudinal seam, butt and double strap, will have an efficiency from about 70 to better than 90 per cent and therefore the seam in a patch on a butt strap boiler will almost invariably be weaker than the longitudinal seam.

Because a firesheet is bulged does not mean that a patch is necessary; the bulge may be so small that, except for extra precaution to keep the depression free from internal deposits, no changes will be necessary. Again, the bulge may be gradual, and while a large area may be covered, the reduction of plate is slight. In this case, the bulge can be driven back and the boiler made practically as good as before.

Let the inspector look over any bulged firesheet before any cutting is done. E. R. D.

Trouble With Steam Piping

At one time I had under my charge 2 steam pumps used for boiler feeding, but only one pump was used at a time, the steam pipes for both pumps were arranged as shown in Fig. 1 by the dotted lines, and when No. 1 pump was in use the pipe leading from the tee to steam valve on pump No. 2 was always full of water, and when No. 2 pump was in use the pipe from the tee to steam valve on pump No. 1 was also full of water, causing more or less water hammer at times. I changed the piping to that as showing in the full lines shown in Fig. 1. By placing the steam valve for pump No. 2 close to the steam valve on pump No. 1, in this arrangement both steam pipes between the valves and pump were always clear of water, and as both pumps were set close together there was no inconvenience of handling pump No. 2 due to the steam valve being near the steam valve on pump No. 1. Of course, valves could have

been placed for both steam pipes at the tee, where the pipes branch off, but this would have been more expensive. Besides, in opening and closing these valves, climbing a ladder would have been necessary. Also, in this arrangement only one steam cylinder lubricator was necessary.

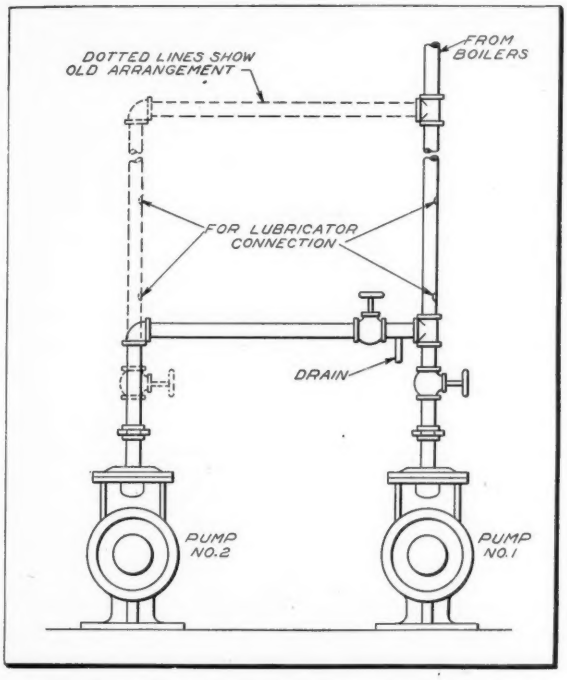


FIG. 1. PUMP AND STEAM PIPE ARRANGEMENT

Some time ago, while making some changes in the piping system in our plant and while disconnecting some of the pipes from ells, tees and valves, I noticed that some of the pipes, which were run horizontal, were wasted away on the bottom to half their original thickness, as shown in Fig. 2. This was a surprise to me, as this piping had only been in use about 3 yr. On some ends of the pipes some of the threads were entirely wasted away, as shown in Fig. 3. The pipe was 1¼-in. standard size.

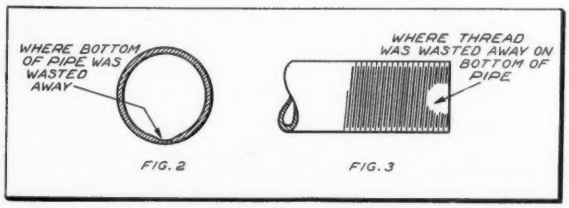


FIG. 2. STEAM PIPE CORRODED BY CONDENSATE
FIG. 3. CORRODED PIPE END

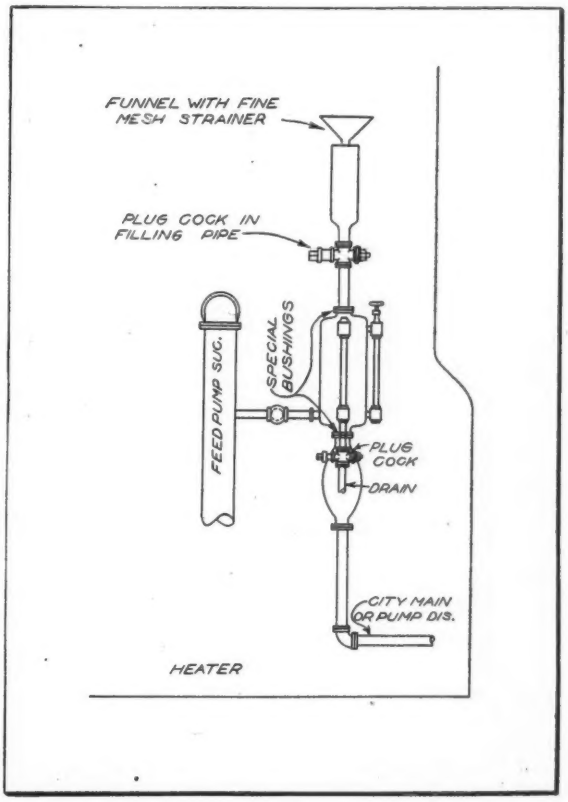
In thinking the matter over I came to the conclusion that at times water from condensed steam would stand in some of this pipe for days, and this water corroded the pipe. No doubt any little water hammer or jar would have broken the pipes at the joints. After this experience all piping was examined, especially that in which condensed steam is standing quite often.

No doubt the above conditions exist in many other steam plants, where the engineer is under the impression that all the piping in the plant is in good condition, as it probably has only been in use for a short time, but the above experience shows that this is not always true.

H. A. JAHNKE.

Boiler Compound Feeder

THE DIAGRAM shows what I use very successfully for feeding boiler compound,—an inverted ½-pint Detroit lubricator with the connection changed. Where you would drain the lubricator, I used a special bushing for pipe for filling, and where you ordinarily fill the top of glass, in this case I use to drain lubricator of water, this happened to be a small cup not in use, so I used it as illustrated. I thin down, if thick, boiler compound



LUBRICATOR USED AS COMPOUND FEEDER

and put it through a fine mesh strainer in funnel and at times I can feed a fine stream in sight glass until all has gone to the boilers. A larger cup would be much better and the bushings are special, owing to the fact that the threads in the cup are not standard. Height of water in the heater makes no difference.

JOSEPH WEBSTER.

ON FRIDAY EVENING, Feb. 5, 1915, Chas. Piez, President of Link Belt Co., of Chicago, will speak before the Detroit Engineering Society on "Coal Handling Apparatus in Its Various Forms."

PRACTICAL ENGINEER

Trade-mark reg. U. S. Pat. Office.

PUBLISHED ON THE FIRST AND FIFTEENTH OF EACH MONTH
At 537 So. Dearborn Street, Chicago, Ill., by the
TECHNICAL PUBLISHING CO.
New York, 150 Nassau St.

Notify us at once of any change of address, giving the old and the new address, so that your paper may always reach you promptly.

Copyrighted, 1915 by Technical Publishing Co.
Entered as second class matter May 1, 1908, at the Post Office at Chicago, Illinois, under the Act of March 3, 1879.

Circulation of this issue, 22,500.

CONTENTS

Ashes, Handling of 87
Baffles, Steam 38
  Settings and Materials for 12
Baffling, Methods of 23
Blowing Off and Blowoffs 32, 94
Boiler Accessories. 26
  Capacity 15
  Foundations 7
  Materials, Strength of 7
  Compound Feeder 97
  Operation 55
  Plant, The. By R. T. Strohm 6
  Staying 20
Boiler Treatments for Scale 84
Boilers, Cleaning of 84
Boilers, Laying up 95
Boilers, Patching 89, 95
Boilers, Repairing 89
Boilers, Retubing 90
Boilers, Special, Details of 52
Boilers, Water-Tube 42
Brickwork, Repair of 91
Coal Measurement at the Plant 67
Combustion Spaces, Proportions of 14
Compounds, Boiler 81
CO_2 Recorders 79
Damper Regulators 64
Domes 39
Draft Losses 24
Draft Regulation 63
Dry Pipes and Domes 39
Feed Line Discharge 32
Feed Water, Measurement of 68
Feed Water Regulators 25
Firebox, Proportions of 14
Firing of Furnaces 55
Flow Meter, Cushion on. By M. C. Saeger 73
Foundations 7
Fuel Bed 62
Furnaces, Firing 55
Fusible Plugs 31
Gage Cocks 30
Gas Analysis 77
Gasket, Renewing 95
Handholes, Manholes and 95
Human Element, The 98
Joints, Riveted 18
Manholes and Handholes 95
Pipe Trouble 97
Plates and Joints, Testing of 88
Plugs, Fusible 31
Repair of Brickwork 91
  Valves and Piping 93
Repairing Boilers 89
Riveted Joints 18
Scale, Boiler Treatments for 84
Safety Valves. 35
Scientific Management of Power Plants. By Walter N. Polakov. 1
Settings 10
Settings and Baffles, Common Materials for 12
Soot, Removal of 86
Spacing of Tubes 23
Special Boilers:
  Brady-Scotch Boilers 53
  Continental Boiler 52
  Hawkes Boiler 52
  Lyons Boiler 53
  Smith Vertical Tubular Boiler 53
Winslow Boiler 54
Steam Baffles 38
Steam Flow Measurement 73
Stoker Firing 58
Stokers 59
Strength of Material 17
Superheaters 39
Suspension 8
Temperature Readings 76
Testing of Plates and Joints 88
Tube Cleaners 86
Tubes, Spacing of 23
Valves, Safety 35
Walls 9
Water Columns 26
Water Meters 68
Water, Treatment of 80
Water-Tube Boilers:
  Almy Boiler 42
  Babcock & Wilcox Boilers 42
  Badenhausen Boilers 44
  Bigelow-Hornsby Water-Tube Boiler 45
  Casey-Hedges Boiler 45
  Edge Moor Boilers 46
  Erie City Boilers 46
  Geary Water-Tube Boiler 50
  Heine Boilers 47
  Keeler Boilers 48
  Milne Water-Tube Boilers 48
  Morrison Boilers 48
  O'Brien Boilers 49
  Rust Boiler 43
  Springfield Water-Tube Boiler 50
  Stirling Boilers 43
  Union Boiler 50
  Vogt Water-Tube Boiler 51
  Wickes Boiler 51
  Worthington Sectional Boiler 44

NOW THAT business is looking upward, it is important that the plant be put in the best possible condition to carry maximum load, so that it may be ready to meet all demands. Also to give the best efficiency so that expense may be as low as possible, to permit of manufacturing costs which will attract business in the largest volume.

In the boiler room is the place to begin, looking for opportunity to improve operation, increase output and reduce outgo. Study of the principles and practice embodied in the preceding pages will give the best possible basis for such regeneration.

The Human Element

What we are, what we feel, what we desire, what we experience has its strong influence, not only on character, but on accomplishment. So old, so often repeated, so true, yet so neglected;—this must needs be emphasized, again and yet again, so that some others may see, and, understanding, take heed.

In the leading article in this issue, the chief point is, after all, how to change the organization, for on that depends the using to best advantage of all the knowledge gained by tests and experiments. What's the good of finding out the best conditions for efficient operation of the boiler plant,—then saying, "Now we know how," and proceeding to let things go on as before, or with a little improvement here and there.

In his recent presidential address before the A. S. M. E., James Hartness brings out several points worth repeating and incorporating into one's scheme of life as to both individual and organization progress.

First, as to individual policy: the need of concentration of activity to avoid ineffective dribbling is evident. A mind can hold but a limited number of things ready for instant service. The rest must be noted, filed and indexed for quick reference. Habit of thought is as important as subject of thought. Carrying through to a conclusion is important and can be cultivated. Drifting from one thing to another is easy—and disastrous. Also, it is more important to have the mind alert and active for new ideas, than to overload it with data and facts. It is more important to know when and why to test a boiler for combustion and evaporation than to memorize the method of figuring efficiency or factor of evaporation.

Habit is the result of repetition, conscious or haphazard. Habits may be formed or may grow;—made good servants or allowed to become bad masters. And daily surroundings are a big aid or hindrance.

Which brings up the matter of the human element of the organization, and the desires and needs of the individuals comprising it. Each one fits some place better than any other. His ability, experience and belief in himself determine this; and the wise executive considers all these in selecting or transferring. Careless employment and discharge are destructive of effectiveness in the organization and of good spirit in employes. But a man who fits his job and believes that it fits him; who has a live interest in getting results, and is stimulated by appreciation and reward when he makes good, is a most valuable asset, and should be parted with only from necessity.

How to create such assets is worthy of earnest and continuous study and effort. Good sense, appreciation of the possibilities of men and machinery, recognition of what is due the company, and a kindly application of the Golden Rule are the materials from which success in this line of organization is builded.

The Factory Fire Chief

In many places, the employer expects the engineer to be the head of the fire fighting force of the shop or building in which he is employed, although it does seem that this responsibility should rest on other shoulders. When it is laid down as one of his duties, however, he should endeavor to make the fire fighting force as efficient as possible. The various kinds of fire fighting equipment for use in buildings are so numerous that it would be impossible to mention all of them here, and the system in use in any instance will depend on the nature of the building, the ideas of the architect and the amount of money that the company is willing to spend for this purpose.

The first requisite of a system of any kind is to have the men drilled in the use of the apparatus. Any fire fighting equipment is infinitely more valuable where all the employes, or those who are required to handle the apparatus in time of fire, are thoroughly familiar with its use, and have had some practice along this line. It is also essential for everybody to know just how and where to get out of the building in case a fire starts. This can be done successfully only if they have had practice and instructions in advance. Every factory should, and most of them do, have a private fire fighting company, and this department should be organized, the work systematized, and the members trained so that they will know just what their duties are. Where the engineer is also the fire chief, it is up to him to see that this plan is carried out.

At Montague City, near Turners Falls, Mass., there is now under way the largest hydro-electric plant in New England, involving the construction of a concrete dam 1000 ft. long by 35 ft. high, a canal 11,700 ft. long, and a power house with capacity of 58,200 hp. The dam is now about half completed, and the enlargement of the old canal, which was formerly in use at that point, is under way. The power house is 250 ft. long by 80 ft. wide, and will be 120 ft. high from foundations to roof. The upper part is of steel and brick, the lower part and passages are of concrete.

Equipment will consist of 6 9700-hp., single-runner vertical water wheels, each driving a 7500-kv.a. generator delivering 3-phase currents at 6600 v. Current will be stepped up by water-cooled transformers to 66,000 v. for transmission over the steel tower line of the Amherst Power Co. to Amherst, Easthampton, Chicopee and Springfield, and to 13,200 v. for transmission to Turners Falls, Millers Falls and Greenfield, Mass. It is expected that the plant will be in operation by Oct. 1, 1915.

Books and Catalogs

The Gas Turbine. By Norman Davey; First edition, 248 pages, 100 illustrations and diagrams; New York, 1914. Price, $4.

Both the theoretical and the practical sides of the gas turbine are exhaustively treated in this volume.

Beginning with the general considerations of the gas turbine as a heat engine, the author describes with the use of considerable mathematics the constant-pressure, single-fluid turbine, the mixed fluid turbine and derived types of that machine. Chapter V is devoted to a thorough discussion of the explosion gas turbine, while Chapter VI deals with the variation in thermodynamic constants and its effect upon efficiency.

The second part of the book, that devoted to the practical gas turbine, outlines the accessory machinery used in connection therewith. Producers and furnaces, turbine wheels, regenerators and condensers, governors and pumps are described and compared.

The question most important in the gas turbine problem, is the fixing of what are the limiting conditions under which it may satisfactorily operate. This is taken up in detail.

The remainder of the book is devoted to the history, progress and future of the gas turbine and a summary of efficiencies and comparison of types.

BULLETINS FROM THE Bureau of Mines, Department of Interior, are now ready, No. 76, of 13 pages, on "United States Coals Available for Export Trade," by V. H. Manning; No. 77, on "The Electric Furnace in Metallurgical Work," 216 pages, by D. A. Lyon, R. M. Keeney and J. F. Cullen, and technical paper No. 76, on "Sampling and Analysis of Coal," by A. C. Fieldner, is also ready. A limited supply of these publications is available for free distribution to those who have satisfactory reason for desiring them. Applications should be addressed to the Director of the Bureau of Mines, Washington, D. C.

FROM THE Direct Separator Co., of Syracuse, N. Y., comes an attractive catalog of flanged steam fittings and steam separators. The fittings as made by this company are all in accordance with the schedules recommended and adopted by the A. S. M. E. and other societies, and known as the 1915 American or U. S. Standard Dimensions. These are made in cast iron, standard and extra heavy weights, for all shapes and all sizes of pipe. The catalog gives a full list of dimensions and prices.

BULLETIN NO. 44,404 describes one of the General Electric Co.'s new line of ventilated commutating-pole motors. This motor has a rated capacity of 80 hp. on 600 v., but, due to the special feature of induced ventilation, has a greater service capacity than motors of the closed type, having the same hourly rating. A description of the motors is given in more or less condensed form, but a more detailed description is given in the company's bulletin A-4171. The new bulletin contains a schedule of speed tables and characteristic curves of the motor.

BOILERS made by Samuel Smith & Son Co., Paterson, N. J., are described and illustrated in a catalog lately received, together with a circular relating to some of the company's special boilers.

WESTINGHOUSE Electric & Mfg. Co., East Pittsburgh, Pa., has recently issued the following publications:

Folder 4387, Westinghouse Electric Drive for Flour Mills, describes the use of electric power in flour mills, showing curves illustrating the energy used in mills of various kinds throughout typical days of operation. The equipment used for different mills is also given.

FEED WATER HEATERS, purifiers, steam separators, oil eliminators, exhaust heads and V-notch water meters with weighing recorders, are described and illustrated in the new 80-page catalog, No. 60, of The Hoppes Mfg. Co., Springfield, Ohio.

PRACTICAL ENGINEER

Trade-mark, Reg. U. S. Pat. Off.

SEMI-MONTHLY

PUBLISHED ON THE FIRST AND FIFTEENTH OF EACH MONTH.

Subscription price in advance in the United States, Mexico or united possessions, $1.00 a year.

In Canada, subscription price, $1.75 a year.

Foreign Countries, subscription price, $2.50 a year.

Address all letters and make all checks and money orders payable to Technical Publishing Co., 537 So. Dearborn St., Chicago, Ill.

Any advertiser is invited to examine our paid subscription lists and Post Office mailing receipts at any time.

ADVERTISING RATES
Display

Full page, one year, each insertion, $60.00.

Half page, one year, each insertion, $35.00.

Quarter page, one year, each insertion, $20.00.

Eighth page, one year, each insertion, $12.00.

Front cover, $150.00 per issue.

Other specified positions, regular rate plus 10 to 50 per cent.

Stippled plates used, but no heavy, black and white plates.

Invoices are rendered monthly and subject to 2 per cent discount within 10 days.

Classified Rates

Per line, 30 cents each insertion.

Advertisements in this section are inserted under regular headings.

No display type allowed, but the first three words may be set in capital letters.

About nine words make a line. Minimum space sold, two lines.

Under classification "Position Wanted," advertisements not exceeding four lines will be inserted once for subscribers free of charge.

All copy should be received at Chicago office 18 days before date of publication.

Circulation of this issue 22,500

Technical Publishing Co.
537 S. Dearborn Street
Chicago

Position Wanted

POSITION WANTED—By engineer, with first-class Canadian certificate, 14 years' experience. Familiar with any high speed, or Corliss engine; d.c. machines, air compressors, etc. Would take position as second in large power plant. Willing to go anywhere in Canada. Total abstainer. Excellent references. Address Box 378, Practical Engineer, Chicago, Ill. 12-15-1

POSITION WANTED—By Sales Engineer with wide experience in selling Steam Engines, Boilers and Power Plant Equipment. Have shop experience and technical education. Can produce results. Address Practical Engineer, Box 379, Chicago, Ill. 1-1-1

POSITION WANTED—By engineer of 35, married, as fireman, assistant engineer or charge of small steam plant. Good repair man. Sober and steady. Will go anywhere in western states. Address Practical Engineer, Box 380, Chicago, Ill. 1-1-1

POSITION WANTED—As Chief Engineer of steam or hydro-electric power plant of 1000 hp. or less. 15 years' experience in central station operation; strictly temperate; best of reference as to character and ability. Middle West preferred. Address Box 376, Practical Engineer. 12-15-1

POSITION WANTED—As Chief Engineer and Electrician; 12 years' experience as chief engineer, electrician and erector of steam and electrical apparatus. Also some refrigerating experience. Age 29. Married. Strictly sober. Can furnish best of references. Can start Dec. 15th. Correspondence invited. S. James Zucchet, 1437 Solon Place, Chicago, Ill. 12-15-1

Wanted

AN OPPORTUNITY for High Class Salesmen. A well known, established concern, manufacturing power plant specialties, wants representatives in the following territories: Syracuse, N. Y.; Louisville, Ky.; Tacoma, Wash.; Birmingham, Ala.; Raleigh, N. C.; Nashville, Tenn.; Duluth, Minn.; Cincinnati, O.; Denver, Colo. Applicants must be able to show good selling record and possess a knowledge of boiler equipment. Excellent opportunity for high class men. Details of experience and references in first letter. Box 375, Practical Engineer, Chicago, Ill. tf.

FREE ENGINEERING BOOKS and power plant tools and specialties for securing new subscribers to Practical Engineer. A dandy chance for the engineer with a little spare time, to get some fine premiums. Send for free descriptive circular and terms. Address Practical Engineer, Subscription Department, Chicago, Ill. tf.

WANTED—Resident subscription agents in all cities of 50,000 population, and over. Many of the largest cities still open. An excellent chance for hustlers to turn their spare time into dollars. Practical Engineer, 537 S. Dearborn St., Chicago, Ill. tf.

WANTED—If you are a dealer or sales agent and can handle an improved line of high grade Steam Specialties including Steam Traps, Reducing Valves, Damper Regulators, Safety Water Columns, Feed Water Regulators, etc., we believe it will pay you to write "Steam Goods," care of Practical Engineer, Chicago, Ill. 1-1-1

WANTED—ALL STEAM USERS to have clean boilers without using compounds or chemicals in any form. Write "Otis," No. 317 Norfolk Ave., Buffalo, N. Y. tf.

WANTED—50-hp., second-hand Engine and 125-volt, d.c. Generator. Must be in good condition. Direct connected Corliss preferred. State particulars and price when writing. H. Van Beckum, St. Francis, Wis. 1-1-1

Help Wanted

WANTED—Agents on commission to sell our Shaking Grates. We will install grates on trial or put in on test at our expense with any grate made. Address Armstrong Mfg. Company, Springfield, Ohio. tf.

WANTED—Agents handling engine and boiler-room specialties in every section for side line paying large commissions. Give experience, lines carried and territory covered. Address Practical Engineer, Box 381, Chicago, Ill. tf.

For Sale

FOR SALE—25 kw. Holtzer Cabot d.c. generator with switchboard; A-1 condition. Lucas & Son, Bridgeport, Ct. 12-15-3

FOR SALE—Good Crosby Indicator with 5 springs, 5 scales, 1 reducing wheel and 1 planimeter, all in good condition in mahogany case. Correspond with G. B. Warner, 2450 Bellefontaine St., Indianapolis, Ind. 1-1-1

FOR SALE—Engines: 10x24 Allis Corliss, $350; 18x36 Hewes & Phillips Corliss, with tangye frame, $900; 20x42 Vilter Corliss, $700; 28x48 Hamilton Corliss, $1200. Duzets & Son, 50 Church St., New York, N. Y. tf.

GROBET SWISS FILES are the standard of excellence in files, and have been for over 100 years. We send post paid, as an introducer, 48 files especially adapted for tool makers and machinists on receipt of $5.00. This is a chance to get a set of files you'll appreciate and we'll get future orders. Montgomery & Co., 101 Fulton St., New York, N. Y. 1-1-1

Patents and Patent Attorneys

PATENTS SECURED OR FEE RETURNED—Send sketch for free search, advice and report. Latest and most complete patent book ever published for free distribution. George P. Kimmel, Attorney, 226 Barrister Building, Washington, D. C. 12-15-6

PATENTS—C. L. Parker, Attorney-at-Law and Solicitor of Patents. Patents secured promptly and with special regard to the legal protection of the invention. Handbook for inventors sent upon request. 186 McGill Bldg., Washington, D. C. tf.

PATENTS THAT PROTECT AND PAY. Advice and books free. Highest references. Best results. Promptness assured. Send sketch or model for free search. Watson E. Coleman, Patent Lawyer, 624 F St., Washington, D. C. tf.

PATENTS—H. W. T. Jenner, Patent Attorney and Mechanical Expert, 606 F St., Washington, D. C. Established 1883. I make a free examination and report if a patent can be had, and the exact costs. Send for full information. tf.

PATENTS—Books, 100 Mechanical Movements and Full Information Free. Expert Service. Best Terms. Write today. Fred G. Dieterich & Co., Patent Lawyers, 606 Ouray Bldg., Washington, D. C. 1-1-3

PATENTS—Send sketch for free search and report. Books on patents and book of reference letters sent free. John S. Duffie & Co., 612 F St., Washington, D. C. tf.

"PATENT YOUR INVENTIONS."—Search free when patent applied for. Charles F. Kincheloe, Patent Lawyer, Woodward Building, Washington, D. C. 10-15-6

PATENTABLE IDEAS WANTED—Send for three free books. R. B. Owen, 28 Owen Bldg., Washington, D. C. tf.

Educational and Instruction

ENGINEERS' POCKET MANUAL, 175 pages, edited by University of Tennessee, will be mailed every subscriber sending in NEW subscription (not your own) to Practical Engineer. Gilt edges; bound in leather.

Technical Books

ENGINEERS AND FIREMEN—Send 10c in stamps for a 40-page pamphlet containing a list of questions asked by an examining board of engineers. Stromberg Publishing Co., 2238 Pope Ave., St. Louis, Mo. 10-1-6

Miscellaneous

WANTED reliable commission selling agents in various States and also Canada to handle powder boiler compounds. Also a superior article, called "Cleaner," which can be most extensively consumed. Address James E. Dale Company, Rahway, N. J. 12-1-4

ENGINEERS, DO YOU WANT to utilize your exhaust steam for heating or drying purposes, without back pressure on your engine? If so, address Monash Engineering Co., 1413 W. Jackson Blvd., Chicago, Ill. tf.

Sparks From The Advertising Pages

During the past year we have told you on this page about the benefits you could derive by reading the advertising pages of Practical Engineer.

We have told you among other things, why advertised products are more reliable than non-advertised products, why they can be and are sold cheaper than non-advertised products, and that you could increase your personal efficiency, also the efficiency of your plant by making use of the products advertised in Practical Engineer.

Now we suggest for a few months in 1915 that, through this page, subscribers to Practical Engineer tell your fellow engineers about the improvements you have effected in your plant by purchasing and installing machinery and materials that are advertised in Practical Engineer. Such information will be of much benefit to them all, and they will certainly appreciate receiving it.

THIS IS THE PROPOSITION

What have you purchased directly or indirectly by reading the advertisements in Practical Engineer that has increased the efficiency, economy, safety or convenience of your plant, and how much? Remember, we want not merely a list of equipment and materials purchased—we want to know about the work the equipment is doing and whether or not it is making good.

Has Practical Engineer put you in touch with a grate, blower, stoker or pyrometer which is saving you coal; with a feed water heater, exhaust head or steam trap which is saving you steam; with a lubricating system or oil filter which is enabling you to economize on oil bills; with valves, unions, packings, scale treatments; with a lubricant which is lessening friction and trouble in your plant; with belting or other transmission material which is better than you previously used; with a gauge glass, pump, boiler or engine which is giving your plant higher efficiency, or with any other power plant product which is proving to be a good investment?

Tell us about them. Tell us in a letter and give facts and figures. Describe the installation, the work it is doing and what it has already accomplished.

It may take you ten or fifteen minutes to write such a description, and as a return favor we will present a leather bound **pocket manual for engineers** to each engineer who writes us a letter giving this information. This **pocket manual** contains valuable tables, logarithms of numbers, squares, cubes, roots, weights and areas of square or round bars, weights of sheets of wrought iron, steel, copper, brass, flow of steam through pipes, calorific value of fuels, loss of head in pipe by friction, etc. All in all, 169 pages of useful power plant information.

The composition of your letter is of secondary importance. What we are after is facts brought out in practical work more than we are after grammatical or literary excellence in letter writing. Just write to us exactly as you would tell a brother engineer about it.